ALBERTA OFFICE OF COAL RESEARCH & TECHNOLOGY

ANNUAL REVIEW 1989/90

Alberta
ENERGY
Research and Technology Branch

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It might look like a view of the solar system, but the cover photo is actually a polarized-light micrograph of carbon fibre in its initial growth stage when made from coal-derived liquids. Methods for making these fibres are being studied at Alberta Research Council.
(photo provided by Alberta Research Council)

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Preamble

The Alberta Office of Coal Research and Technology was established January 20, 1984, by Ministerial Order under the Department of Energy and Natural Resources Act.

The purpose of the Office is to co-ordinate the Alberta government funding needed to identify, investigate and develop coal-related technologies considered to be commercially important during the next decade. Its goals are:

- to minimize the environmental impact of coal production and use in Alberta and elsewhere;
- to enhance the competitiveness of Alberta coals; and
- to develop new uses for Alberta coals.

Appointed to the Office are R. Douglas McDonald as Chairman, and Garnet T. Page and Michael A. Ward as Members. In October 1989, Mr. McDonald became Senior Director-Asia for the Department of Energy, and J.K. Kleta was appointed Chairman of the Office. T. David Brown represents Energy, Mines and Resources Canada as an observer and participates in project reviews.

Initial government funding for the Office was provided by the Alberta/Canada Energy Resources Research Fund (A/CERRF). This has since been supplemented by funding from the Alberta Department of Energy.

Introduction

Chairman's Report

During 1989/90, the Alberta Office of Coal Research and Technology continued to support coal research and technology development primarily through the A/CERRF-funded Alberta Coal Research Program and the Western Canadian Low-Sulphur Coal to Ontario Program. Many projects in these programs were carried out and funded partly by the private sector. Others were funded entirely by the Office and carried out at universities and research institutions. One major project, the Alberta Coal Geology Project, was funded by the Alberta Department of Energy.

All this work was based on the 1983 Alberta Coal Research Strategy, which was revised this year after consultation with the private sector and interested government agencies. This consultation led to research priorities for the 1990s. They are:

- minimizing the environmental impact of coal production and use in Alberta and elsewhere;
- enhancing the competitiveness of Alberta coals; and
- developing new uses for Alberta coals.

These priorities will allow the Office to continue to build upon its past activities and experience, but will require an even greater emphasis on the environmental aspects of coal production and use than previously. Also, they will require greater emphasis on coal quality and transportation technologies.

During 1989/90, projects funded by the Office caused several technologies to advance toward commercial applications. They are listed below.

Environment-Related Technologies:

- Low NO_x/SO_x Burner Demonstration (also related to new uses for Alberta coals);
- Coal Gasification Research and Development; and
- Advanced Coal Combustion Science (improved efficiency and reduced emissions of NOx).

Coal Quality-Related Technologies:

- Coal Agglomeration; and
- Coal/Oil Co-processing (also related to new uses for Alberta coals).

Coal Transportation-Related Technologies:

- Coal Slurry Pipelining (coal/oil or coal/water mixtures).

In addition to these projects, the Office continued to support coal characterization and coal geology studies. These activities are being phased out, however, and budget constraints have forced the University Grants Program to be terminated. From now on, research proposals received from universities and institutions must be considered within the overall context of the revised research strategy and current priorities. This means that all proposals must respond to the needs of industry and have industry support.

This past year, the Office continued to provide administrative support to the joint industry/government technical committees established previously. These committees actively pursued research and technology development in the following areas:

- mining;
- the use of coal for steam generation in heavy oil production;
- coal gasification technology;
- fine coal cleaning;
- sorbent injection; and
- co-processing of coal and heavy oil.

These committees provide a forum for expressing and acting upon mutual interests, and sharing research and development costs on projects aimed at solving operating problems. Currently, the Office is attempting to clarify the role and formulate mutually agreeable terms of reference that clearly define the goals and objectives of these committees. Concurrently, alternative methods for achieving the same end results are being explored.

The Office continues to encourage collaboration among research and development organizations in Alberta, Canada and several countries. Currently, the Office is involved internationally in projects with Japan, the Federal Republic of Germany, and several European countries through the International Energy Agency.

In October 1989, the first Chairman of the Office, R.D. McDonald, was appointed Senior Director-Asia for the Department of Energy, based in Tokyo, where he is helping to encourage investment by southeast Asians in Alberta's energy industry.

In December 1989, an A/CERRF-initiated evaluation of the Office's programs was carried out by a management consulting firm. As a result of this investigation, several measures were initiated and adopted during the second half of the year to simplify the administration of coal research programs, including funding approvals, research agreements and project management.

During 1989/90, the Office received 54 requests for research funding, of which 24 were approved for Office contributions. In addition, funding support was continued for 20 projects approved previously. The total 1989/90 research funding contributions by the Office were $6.63 million, representing 35 per cent of total research expenditures for approved projects.

Day-to-day administration of Office projects is provided by staff in Alberta Department of Energy, Research and Technology Branch (formerly Scientific and Engineering Services and Research Division). Additional assistance, co-operation and considerable support were received from the coal industry, research institutions and intergovernmental organizations.

The results of many investigations supported by the Office are available to industry and other interested parties through technology transfer publications. These are available from the Office or the Alberta Energy/Forestry, Lands and Wildlife information centres in Calgary and Edmonton.

J.K. Kleta
Chairman

Background

Alberta's coal industry provided an important energy source during early development of the province. It continued to contribute significant economic activity until about 1950 when the coal market collapsed because large amounts of oil became available as a replacement fuel. In the mid-1960s, a resurgence occurred in the export market for metallurgical coal and in the provincial market for thermal coal. By 1974, annual production had risen to 9.5 million tonnes.

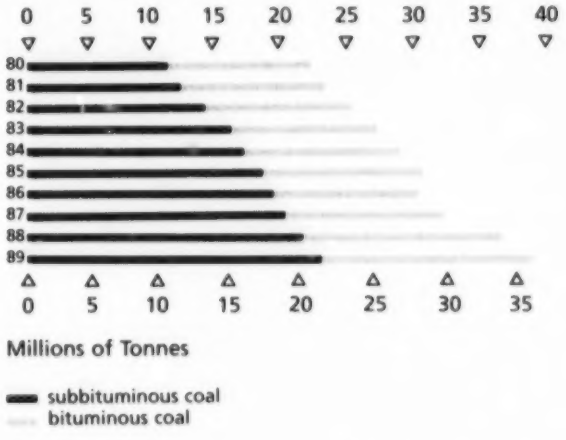
Alberta's raw coal production rose steadily after 1975, reaching 27.7 million tonnes in 1985. It remained at that level in 1986, but has been rising ever since. In 1988, it reached 33.4 million tonnes, a 16 per cent increase over 1987 production. In 1989, raw coal production was up another 5 per cent to 35 million tonnes.

Today, Alberta is Canada's largest coal-producing and coal-consuming province. Alberta's 12 major coal mines produce three types of coal for three different markets. Approximately two-thirds of total production is subbituminous coal produced from plains mines and used for power generation at mine-mouth electricity-generating stations.

High-quality, bituminous metallurgical coal is produced from three mountain coal mines for export to the steel industries in Japan, Korea and Brazil. Low-sulphur bituminous thermal coal is produced from two mines in the foothills region of Alberta for export to Ontario, Japan and Korea. Also, five small mines in the plains area of the province supply coal for domestic use.

Although the international coal market is still in an oversupply situation, several thermal coal mines in the foothills region have been approved for development when export markets warrant. Income earned by Alberta's coal producers is derived from exports of bituminous coals, and from subbituminous coals used by Alberta utility companies to produce more than 91 per cent of Alberta's electricity. Approximately 2 400 people are directly employed by Alberta's coal producers.

Raw Coal Production



These statistics emphasize some of the benefits and the importance of Alberta's coal industry, but there are other advantages to having a healthy coal industry in the province. For example, coal mines provide a high economic and social return on the affected land. Also, the sale of coal to other countries improves Canada's trade balance, contributes to expansion of the transportation network, and fosters growth in the provincial construction industry during periods of expansion. Other direct benefits include financial contributions to all levels of government, and the purchase of goods and services within Alberta.

It is expected that Alberta's coal industry will continue to supply the low-sulphur fuel that makes electricity available to all Albertans at little economic or environmental cost, and encourage the growth of secondary industries, provide a reliable and economic energy source for recovery of the province's heavy oils and bitumen, and make other significant contributions to the province's economic base.

To optimize these benefits, however, coal-exporting companies must continue to capitalize on the upturn in the Japanese economy and improvements in prices paid for Alberta coal. This situation is somewhat hampered by a rising Canadian dollar relative to several currencies. Nevertheless, deliveries of bituminous metallurgical and thermal coals increased by two per cent and eight per cent, respectively, in 1989. This is a record for coal exports. Also, Alberta's coal-fired power plants used five per cent more subbituminous coal in 1989 versus 1988.

Today's market conditions make it essential that Alberta coal producers use the most efficient and economical technologies available in coal exploration, production, preparation, upgrading, transportation and marketing. Increasingly, overseas customers are demanding coal and coal products that exhibit specific qualities and behaviour. This means that coal producers must know more about the combustion characteristics of their products. They must also be involved in the development of new technologies such as agglomeration, coal-water fuels, and other upgrading processes that will produce coal products tailored to market requirements.

The Alberta coal industry's response to these difficulties and challenges is expressed in the Alberta Coal Research Strategy, published in November 1983. This document was the result of extensive discussions among individual companies and the provincial government. In 1984, the Alberta Office of Coal Research and Technology was established. Subsequent industry proposals that were submitted to the Office resulted in research and development projects funded jointly with the Alberta government.

Other research projects funded by the Office have been carried out by the Alberta Research Council and the Coal Mining Research Company.

Another important function provided by the Alberta Office of Coal Research and Technology is the co-ordination of coal research and development activities within Alberta, as well as between Alberta and national and international agencies.

This activity has led to better integration among the various coal research groups in Alberta. Also, it has resulted in a stronger focus on the needs of industry, and has produced international contacts and greater international co-operation.

The Office has directly influenced research and development activities within Alberta by funding projects jointly with the following: individual coal-producing companies or groups of companies, other government agencies, universities, private research organizations, consultants, utilities, equipment suppliers and agencies in other countries.

The Office is influencing coal research and development elsewhere by participating on various national and international committees, including the International Energy Agency's Working Party for Fossil Fuels, and the Canada/Japan Coal Conversion Research and Development Committee.

Coal Research Strategy

Research Rationale

Consistent with the views of the Government of Alberta, the Alberta Office of Coal Research and Technology believes the private sector should take the lead in identifying and managing appropriate research and development programs, as well as implementing and commercializing the results. The role of the Office and other government agencies such as the Alberta Research Council, along with universities and research organizations such as the Coal Mining Research Company, is to support the private sector as necessary to achieve the desired technical results most efficiently.

While there is a recognized need for longer term research and development, as well as basic research to facilitate a better understanding of coal properties and uses, the critical time for commercial expansion and economic development of the province's coal resources will be from 1992 to 1998. During this time, growth in thermal coal use throughout the world is probable, but Alberta's share of the market will be influenced by increased competition from other coal exporters. The extent to which this expansion of thermal coal use can be realized, however, will depend on the prices of other energy supplies, such as natural gas and oil, and the relative social and environmental acceptance of coal versus other fuels or nuclear power.

Towards this end, in 1984 the Alberta Office of Coal Research and Technology identified initial funding through the Alberta/Canada Energy Resources Research Fund of approximately $20 million in support of research, development or demonstration projects. It was anticipated that similar funding would be forthcoming from the private sector. Thus far, contributions from industry have exceeded $30 million.

A portion of the funding is being used for longer term or fundamental research directed toward innovative technologies related to production and use of Alberta coals.

Alberta must collaborate closely with research groups elsewhere to ensure that maximum benefit is derived from the total international coal research and development effort, and to define its intermediate- and long-term plans within this context.

In pursuing its objectives, the Alberta Office of Coal Research and Technology works closely with The Coal Association of Canada and the Alberta coal industry to establish research and development priorities. In addition, the Office maintains world-wide contacts with researchers engaged in coal-related studies.

Administrative Framework

The Alberta Office of Coal Research and Technology does not have in-house facilities to carry out research projects. Rather, its primary role is to provide funding for approved coal research projects. Therefore, procedures have been established to ensure sound project management and financial control of approved projects. For each project, specific agreements are signed that define the terms and conditions under which the project will be conducted and funded. These agreements also define the respective rights to new project technology ownership and use.

After proposals have received thorough consideration, those falling within the interests of the Office are discussed in detail with the applicant, and are often referred in confidence to one or more experts for detailed technical review.

An Alberta government interdepartmental group has been established to review and comment on the implications of the proposed research on their areas of responsibility. This group includes representatives from the Energy Resources Conservation Board and the departments of Forestry, Lands and Wildlife, Economic Development and Trade, Environment, and Community and Occupational Health.

Approval of research proposals by the Alberta Office of Coal Research and Technology is based on the results of these reviews, relative funding contributions and the likelihood that proposed research will contribute to achieving the goals of the Alberta Coal Research Strategic Plan. Those projects funded by the Alberta/Canada Energy Resources Research Fund are submitted subsequently to the A/CERRF Committee for approval.

Technical Committees

While the overall objectives of the Alberta Office of Coal Research and Technology are still guided by the Alberta Coal Research Strategic Plan, it is recognized that the process of choosing which projects ought to be initiated requires a flexible decision-making structure.

Thus, a process has evolved to assist program planning. It involves consultation with industry to identify issues, priorities and potential partners of the Office in new programs and projects. If, as the result of this consultative approach the potential for development of new technology is sufficiently high to attract industry participation and funding, a broad plan for research is developed and a technical committee is established to oversee the program.

Typically, the executive of a technical committee comprises co-chairmen representing industry and the Office, a consultant as secretary and a project manager.

Following establishment of a technical committee, project specifications are developed and calls for proposals are issued to qualified firms and research institutions.

After proposals are received and reviewed by technical committee, working groups are normally formed to manage individual projects. These groups usually comprise companies that are interested in a particular issue and are willing to contribute funds. Working groups pursue problems, enter into contracts, form joint ventures among themselves and seek funding from governments.

Generally, government funding agencies provide 50 to 60 per cent of the funds needed for precommercial research (defined as investigations that precede commercial-scale developments). Occasionally, working groups will proceed without government participation. Funding arrangements are kept flexible to accommodate participants, and respond to the nature and risk of the problem under investigation. When projects are completed, working groups are disbanded.

Full reports on projects are available only to those participants who contribute funds. The question of confidentiality is left to the discretion of working groups. Summaries of results can be released to others, particularly to attract additional participants to later phases of any investigation.

Technical committees act as co-ordinating and collaborative agencies. They make recommendations regarding courses of action and whether projects ought to be pursued. Then, any decisions as to project funding are made by senior management of participating companies and agencies.

A technology transfer publication, titled *The Technical Committee Approach to Coal Research,* provides more detail. It is available from Alberta Energy/ Forestry, Lands and Wildlife information centres in Calgary and Edmonton.

Research Priorities

Since the Alberta Coal Research Strategy was prepared in 1983, several important events have occurred that could significantly affect Alberta coal producers, particularly those depending on export sales.

For example, Ontario Hydro is considering the use of more low-sulphur western Canadian coals to help meet provincial acid gas emission guidelines and establish a reliable domestic coal supply. This has resulted in a commitment by both industry and government to reduce the delivered cost of western Canadian coal in Ontario.

In Alberta, emphasis is being placed on expanding opportunities to use coal in place of natural gas to generate steam for enhanced oil recovery operations.

World-wide, the development of new coal-use technologies is generating demand for certain types of internationally traded thermal coals. Suppliers are now aware they should be providing thermal coals tailored to these new systems. Success in these markets will depend on having a better understanding of the performance characteristics of coal products under different operating conditions. Coal gasification developments are of particular interest to the Office and Alberta coal producers.

These changes have been influential in bringing about some modifications to the research priorities of the Alberta Office of Coal Research and Technology. Currently, those priorities are as follows:

- to develop and apply technologies that help expand opportunities to use coal in Alberta, particularly for producing and upgrading heavy oil and bitumen. Currently, several projects are under way to encourage the use of coal to displace natural gas for steam raising in enhanced heavy oil schemes;
- to develop and apply technologies that will have a significant effect on reducing the delivered cost of Alberta coal in Ontario markets or those in the Orient. Emphasis is being placed on coal production and transportation costs, as well as improved fine coal processing;
- to develop technology that will lead to new manufacturing opportunities within Alberta; and
- to develop and apply technology that will help establish and/or improve the quality of Alberta coals or coal-derived products, as required for emerging coal utilization technologies in Ontario or the Orient. Processes and technologies include blending, upgrading, gasification and coal-water fuels.

Research and Technology Programs

During 1989/90, the projects administered by the Alberta Office of Coal Research and Technology were supported by three sources of funding: Alberta/Canada Energy Resources Research Fund, Department of Energy, and governments participating in the Western Canadian Low-Sulphur Coal to Ontario Program.

Projects under way in each of the three programs are described in the following section.

A/CERRF-Funded Projects

Resource Evaluation

In applying technology to the challenge of making Alberta coals more competitive in various markets, a significant opportunity is posed by the need to match coal quality to coal uses and reduce costs related to coal exploration and mine planning.

Traditionally, attempts to find coal have involved outcrop inspections and expensive core-hole drilling to obtain information on subsurface rock geometry, hydrogeology and coal quality. The latter characteristic is particularly important because it indicates whether coal seams found by exploration methods are commercially valuable. Recent customer demands for tighter coal specifications, however, are causing more core holes to be drilled to isolate coals capable of satisfying particular requirements. This increases the costs of coal exploration and is an important impetus behind current research into alternative, geophysical methods of evaluating coal quality while the coal is still in the ground.

To this end, researchers are attempting to correlate seismic, direct-current electric, magnetic and electromagnetic data from above-ground surveys of prospective coal fields with laboratory analyses of drilled cores. In this way, it is believed that less-expensive methods will be found to locate coal and evaluate its characteristics.

Since 1985, the Alberta Office of Coal Research and Technology has helped fund nine coal resource evaluation projects, six of which have been completed and were described previously. The three remaining projects which were in progress this year are described in the following section.

Seismic Modelling of Shallow Coalfields

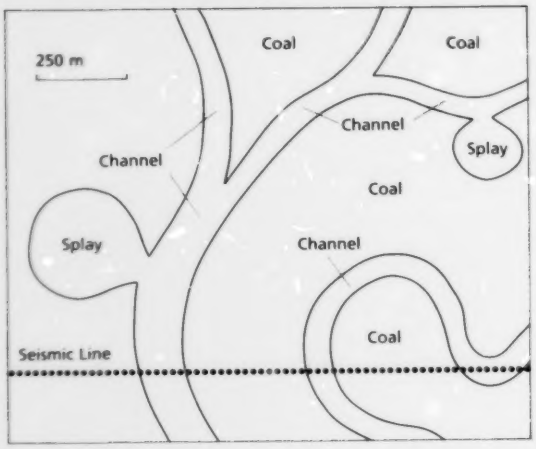
UNIVERSITY OF CALGARY (D.C. LAWTON), CALGARY

In recent years, experimentation with a technique known as surface reflection seismography has indicated that it could be used to search for and evaluate coal in situ, but its use has been limited to determining whether coal is present. This project attempted to demonstrate that quantitative interpretation of coal reflection seismic data is possible. By first comparing synthetic seismograms with information from acoustic and density drillhole logs obtained from coal deposits, followed by two- and three-dimensional seismic modelling, it was anticipated that the thickness, geometry and number of coal seams in a deposit could be interpreted from high-quality seismic data.

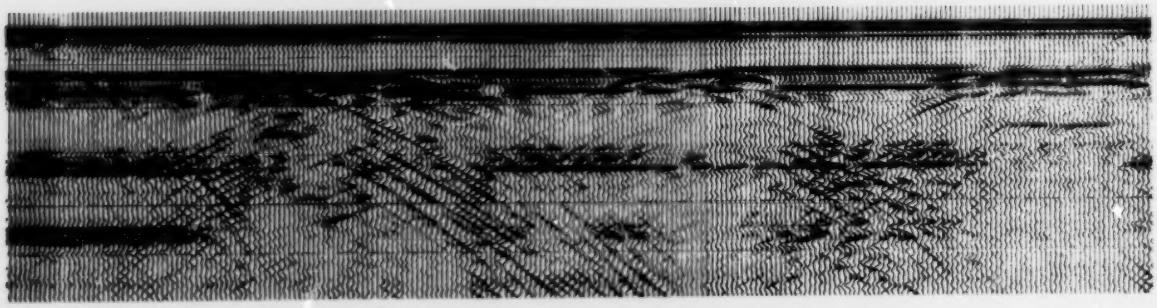
In the initial phase of this study at the Whitewood and Highvale mines, interpretation of drillhole logs, in conjunction with the results of numerical and physical modelling experiments, revealed that density contrasts between coal and host sediments were primarily responsible for the reflectivity characteristics of plains coal. Furthermore, studies of synthetic seismograms showed that small variations in seam thickness and separation significantly affected the overall seismic response. Signal resolution, however, was dramatically affected by the data acquisition geometry used in the field. It was shown that near shot-receiver offsets are preferred in seismic exploration for shallow coals. Further, it was observed that reflection seismic surveys can be useful in mapping coal pinchouts and wash-out zones ahead of mining operations.

Beginning last year and continuing this year, high-resolution reflection seismic data were collected at a coal-mine near Camrose. This site was chosen because it allowed field testing of approaches learned from the modelling work, and comparisons could be made with results from earlier seismic investigations at this site. A significant improvement in data quality was achieved in the new survey. This was attributed to better energy coupling at the seismic source, improved receiver spread geometry, a greater number of recording channels, high subsurface multiplicity, and the use of instruments with fast digital sampling rates and wide dynamic range. All major coal seams could be mapped from the data, including splits and partings in a major coal zone.

Plan View of Physical Model, Showing Channels of Various Widths and Depths, and Crevasse Splay Deposits



A physical model of a delta-plain coal deposit was constructed at the University of Calgary. It was made from Plexiglas, polyvinylchloride, polyethylene sheeting and cement. A simulated coal zone and other geological features were incorporated to determine whether surface reflection seismic measurements made over the model would delineate the features of interest.



Seismic data recorded from physical model.

It was found from the physical model work that channels greater than 25 m wide at a depth of 125 m can be resolved by the seismic method, and differences in channel thicknesses of 7 m are detectable under optimum conditions.

Publications

Lawton, D.C. 1990. Seismic Modelling of Shallow Coalfields. Final Report to the Alberta Office of Coal Research and Technology.

Lawton, D.C. 1990. Density-Based Reflectivity in Seismic Exploration for Coal in Alberta, Canada. Accepted (June 17, 1990) for publication in GEOPHYSICS.

Lawton, D.C. and H.V. Lyatsky. 1989. Advances in Reflection Seismic Methods for Shallow Coal Exploration in Western Canada: Advances in Western Canadian Coal Geoscience - Forum Proceedings, Alberta Research Council Information Series No. 103, 330-340.

Lyatsky, H.V. 1988. Reflection Seismic Study of a Shallow Coalfield in Central Alberta. M.Sc. Thesis. Department of Geology and Geophysics, University of Calgary.

Lyatsky, H.V. and D.C. Lawton. 1988. Application of the Surface Reflection Seismic Method to Shallow Coal Exploration in the Plains of Alberta. Canadian Journal of Exploration Geophysics, 24:124-140.

Downhole Geophysics

TRANSALTA UTILITIES CORPORATION (CALGARY) AND OTHER PARTICIPANTS[1]

This research project was initiated in 1986 to study the practical application of downhole geophysics to the quantitative determination of geotechnical and hydrological parameters in overburden materials. The objective is to identify and refine methods that will improve the collection of geotechnical and hydrological data for open-pit coal and oil sands mines in western Canada.

Currently, most of the data needed to design and operate a typical open-pit mine come from core samples taken from exploration boreholes. These cores are analysed for the various physical characteristics that affect mine design and cost. Core drilling and laboratory analyses are expensive, however, causing mine designs to be based on a limited amount of data.

It is believed that downhole geophysics could provide large amounts of supplementary information on overburden characteristics at a low cost. Although the use of instrumentation for downhole geophysical measurement is well established, it remains to be demonstrated that quantitative interpretation of data for physical characteristics can be achieved for Alberta's mining conditions.

Promising geophysical methods were evaluated during earlier phases of this research. Subsequently, some of the participating companies supplied downhole geophysical data and corresponding measurements of geotechnical and hydrological properties to establish a data base from which correlations could be derived. Although some correlations were found, they needed to be strengthened. It was felt that improved data handling, correction and analysis procedures, and expanded data sets were needed.

Subsequent work on one of the geotechnical data sets demonstrated that improved data correction and analysis procedures are effective for strengthening the correlations. Results for direct shear test parameters, bulk density, Atterberg limits, natural water content and glacially deformed bedrock were particularly encouraging. Deformed and undeformed materials were successfully differentiated using geophysical log data at two sites.

At year-end, collection of additional hydrological data was in progress. Work on the evaluation of water tables, gravimetric water content and hydraulic conductivity continued.

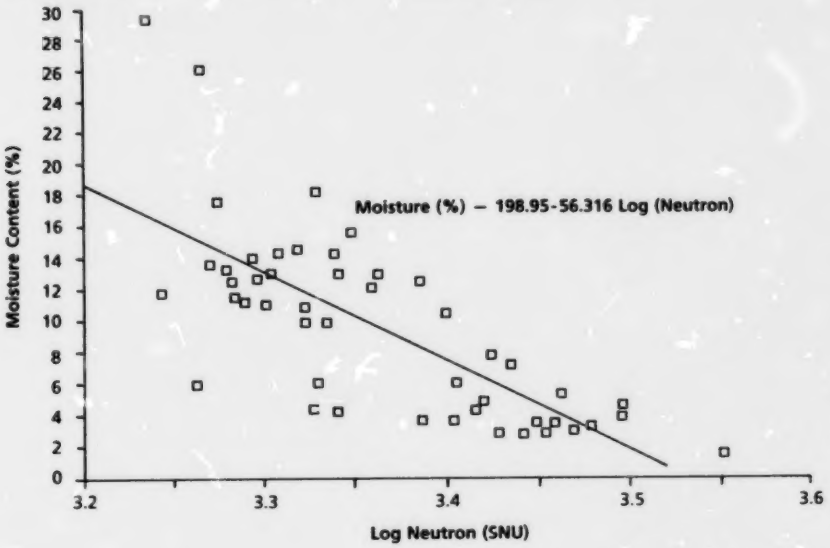
[1]Other participants in Phase I were: Fording Coal Limited, Manalta Coal Ltd., Monenco Consultants Limited, Suncor Inc., Syncrude Canada Ltd., Klohn Leonoff Ltd., Golder Associates, Terracon Geotechnique Ltd., Atomic Energy of Canada Limited, Alberta Research Council, CANMET, and the Office of Coal Research and Technology. The Coal Mining Research Company provided project management.

Other participants in Phase II were: Fording Coal Limited, Klohn Leonoff Ltd., Manalta Coal Ltd., Monenco Consultants Limited, Saskatchewan Power Corporation, Suncor Inc., Syncrude Canada Ltd., Terracon Geotechnique Ltd., Alberta Research Council and CANMET. The Office of Coal Research and Technology was assisted by the Coal Mining Research Company.

Other Phase IIIA participants were: Manalta Coal Ltd., Monenco Consultants Limited, Saskatchewan Power Corporation, Syncrude Canada Ltd., BPB Wireline Services Limited, N. Wade Holdings, Alberta Research Council, Coal Mining Research Company (which acted as Project Manager) and the Office of Coal Research and Technology. Expert advice was provided by W.S. Keys of Geokeys and C.J. Mwenifumbo of the Geological Survey of Canada.

Other Phase IIIB participants were: Manalta Coal Ltd., Monenco Consultants Limited, Syncrude Canada Ltd., BPB Wireline Services Limited, N. Wade Holdings, Alberta Research Council, Coal Mining Research Company, and the Department of Western Economic Diversification. Expert advice was provided by W.S. Keys of Geokeys and C.J. Mwenifumbo of the Geological Survey of Canada.

Log Neutron vs Moisture Content Data from an Alberta Coal Mine



A preliminary evaluation of a full-wave sonic tool was completed. Field trials were conducted for a variety of logging devices, including spectral natural gamma, temperature, several types of resistivity designs and a portable neutron moisture probe for monitoring shallow holes.

Currently, the final phase of this study is under way. It involves further refinements of the relationships established to date.

Although the Alberta Office of Coal Research and Technology is not providing financial support for this last phase, all technical information that it generates will be made available to the Office.

Publications

TransAlta Utilities Corporation. 1989. Downhole Geophysics Project Phase IIIA Progress Report.

TransAlta Utilities Corporation. 1988. Determining Geotechnical and Hydrogeological Parameters Using Downhole Geophysics in the Canadian Plains: Phase II. Correlations of Existing Data.

TransAlta Utilities Corporation. 1987. Determining Geotechnical and Hydrogeological Parameters Using Downhole Geophysics in the Canadian Plains: Phase I. A Review of Potential Applications.

Surface Geophysical Techniques for Foothills and Mountain Coalfield Exploration

ESSO RESOURCES CANADA LIMITED (CALGARY) AND OTHER PARTICIPANTS[1]

The objective of this project is to test and evaluate the application of high-resolution, surface geophysical techniques for defining coal geology and mining targets in a variety of moderately complex topographic and geologic settings in the foothills and mountain regions.

This work is an extension of earlier investigations at three coal-mines in the plains region. While 50 years' experience with surface geophysical methods in petroleum and metal exploration suggests that suitable measurement technology is available, the economic value of these techniques in coal exploration is still uncertain.

For example, it is known that high-resolution geophysical methods demand better-than-standard topographical surveys. Also, steeply dipping beds must be mapped with a dense network of measurement points. The large volume of data collected from such a program demands sophisticated data management and processing techniques. Therefore, if these methods are to be useful to

[1]Other participants were: Crows Nest Resources Limited, Manalta Coal Ltd., Smoky River Coal Limited, Quintette Coal Limited and Luscar Sterco (1977) Ltd. The project was managed by the Coal Mining Research Company.

Alberta's coal industry, they must be at least as effective as, and less costly than, conventional drilling programs designed to obtain an equivalent amount of information.

In this three-year project, increasingly complex geological settings are being investigated to accommodate the variety of geology and topography found in Alberta. The studies cover features such as folding, faulting, dipping strata and tectonically thickened coal under topography that varies from flat to rugged.

During Phase I studies carried out in 1988/89, seismic lines were run at the Smoky River and Coal Valley mines. The resulting reflection seismic profiles indicated structures generally consistent with the interpreted stratigraphy. The more complex topography at the Smoky River site, however, caused some difficulty in data processing. This led to the conclusion that better data on subsurface velocity control should be obtained from the downhole geophysical logs to ensure correct data interpretation. Also, additional work was warranted to refine and document the findings, as well as to compare the interpreted results with actual core findings. These activities were conducted in Phase II.

Phase II results from the Springhill coalfield in Nova Scotia showed that 5-m spacing of the seismic receivers (geophones) can provide better data than the normal, wider spacing in shallow depths. This reduced spacing was then used during the fieldwork at a mine near Telkwa, British Columbia. The interpretation of seismic data was confirmed by the on-site geology.

Some of the data from Phase I were reprocessed to eliminate the interference of electrical effects caused by physical conditions such as overburden and wet zones. This reprocessing was accomplished by "migrating," which matches known geology to the corresponding data and repositions the remainder of the data.

Thus far, the project has shown that useful reflection seismic profiles of the subsurface can be obtained in gently dipping, monoclinal strata underlying gently rolling topography, as well as more geologically complex settings. The combination of several data manipulation techniques is providing realistic geophysical information.

Phase III work will be conducted during 1990/91.

Publication

Coal Mining Research Company. 1989. Foothills/Mountain Surface Geophysics Project. Phase I Report. Prepared on behalf of Esso Resources Canada Limited and a joint venture group of companies.

Mining Technical Committee

In recent years, several research organizations, companies and funding agencies in Alberta have been involved in geomechanical studies of Alberta's resources, including coal, but these investigations have been carried out independently of each other. For instance, the Office has supported 14 coal-mining research projects since 1985, and another is under way in the Western Canadian Low-Sulphur Coal to Ontario Program. In May 1988, the Mining Technical Committee was formed to co-ordinate research and development funding among federal and provincial governments and private organizations in the area of coal production technology.

The technical committee[1] comprises representatives of coal producers, research and development agencies, and the Alberta and federal governments.

The committee identified the following priority areas for investigation:

- mining costs;
- optimal recovery of resources; and
- product quality.

The committee is co-ordinating mining technology components of research associated with reducing the delivered cost of western Canadian coal in Ontario, and continues to be involved with a project initiated last year, namely:

- Surface Geophysical Techniques for Foothills and Mountain Coalfield Exploration.

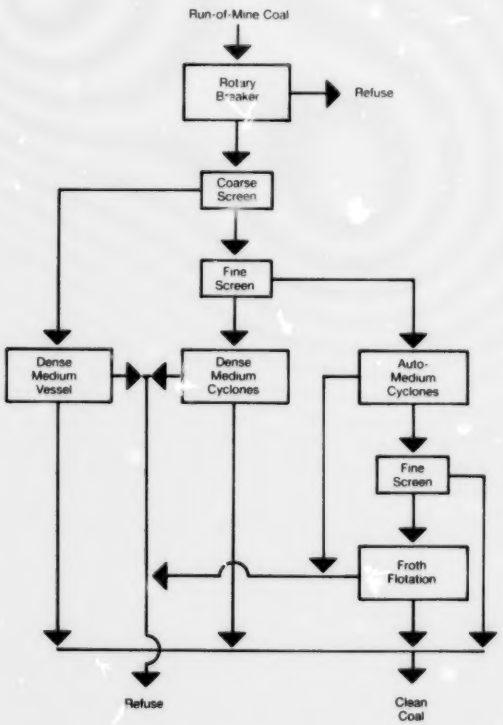
Meanwhile, the Office published a technology transfer booklet describing several mining technology studies. Titled *Advanced Coal Mining Techniques for Alberta*, it is available from Alberta Energy/Forestry, Lands and Wildlife information centres in Calgary and Edmonton.

[1]Committee members on March 31, 1990 were: Quintette Coal Limited, Obed Mountain Coal Company Limited, Unocal Canada Limited, TransAlta Utilities Corporation, Luscar Ltd., Esso Resources Canada Limited, Luscar Sterco (1977) Limited, Fording Coal Limited, Smoky River Coal Limited, Smoky River Holdings Ltd., Crows Nest Resources Limited, Gregg River Resources, The Coal Association of Canada, CANMET, Ontario Ministry of Energy, Department of Western Economic Diversification, Alberta Geological Survey, British Columbia Mines, Energy and Petroleum Resources, Saskatchewan Energy and Mines, Alberta Environment, Alberta Culture, and the Alberta Office of Coal Research and Technology, assisted by the Coal Mining Research Company.

Preparation and Upgrading

In a world coal market characterized by considerable competition, depressed prices and emerging coal-use technologies, consumers have become more demanding about product consistency in terms of combustion characteristics, ash production and the formation of air pollutants. To satisfy these demands, techniques for removing non-combustible mineral matter and moisture in coals are constantly being improved. This not only allows producers to supply higher quality coals, but also minimizes the costs of shipping non-combustible substances having no economic value.

Although washing continues to be the most common coal preparation method, in Alberta it generates substantial quantities of tailings formed from the clays and fines associated with Alberta coals. These tailings represent lost product and require large storage lagoons as an environmental protection measure. Therefore, alternatives to current washing techniques are needed.



As modern fuel standards have become more stringent in response to the availability of new or improved combustion technologies, coal researchers world-wide have begun to develop methods to upgrade coal into products from which most of the nitrogen and sulphur have been removed, or which have been energy-enhanced.

These types of investigations are being pursued in Alberta, particulary those aimed at upgrading bituminous and subbituminous coals to enhance their energy content and combustion performance characteristics, and to recover more fines in the form of economically valuable products.

The results of some coal preparation and upgrading studies were reported in the technology transfer publications, *Coal Preparation Research in Alberta;* and *Studies of Fine Coal Cleaning and Upgrading Processes for Alberta Coals.* Both publications are available from Alberta Energy/Forestry, Lands and Wildlife information centres in Calgary and Edmonton.

Twenty coal preparation and upgrading projects have been supported by the Office since 1984. The following section contains descriptions of five that were active in 1989/90. An additional three research projects are described in the section dealing with the Western Canadian Low-Sulphur Coal to Ontario Program.

Coal Production Program Planning

COAL MINING RESEARCH COMPANY, DEVON

The services of Coal Mining Research Company personnel were provided on an as-required basis to assist the Office with the development of research programs that integrate coal production with transportation and advanced combustion research already in progress.

Subjects investigated this year included the following: a catalogue of persons and firms having expertise in geomechanics and mining engineering research; the potential for application of geostatistics to coal production; the commercial potential for extraction of heavy metals and rare earth metals from coal ash; and assessment procedures for coal production technologies.

It was found that there is no catalogue of geomechanics performers available for Canada and it was suggested that a central agency should be encouraged to assemble such a catalogue. It was also learned that geostatistics have been applied to the Alberta coal problem, but a need exists for well-documented case histories and innovative applications of techniques. Thus, a geostatistics applications demonstration program is warranted.

With regard to the world steel industry, it is highly cyclic (exhibiting a seven- to eight-year period), with supply lagging demand. The current surge in demand for metallurgical coal is a temporary phenomenon and an artifact of the supply/demand lag.

Certain metals, notably titanium, are abundant in ash from Alberta coals. They represent a potentially lucrative by-product from power plants if an efficient separation technology could be devised. This led to the conclusion that fundamental research into the separation of heavy metals from silica melts should be encouraged.

The purpose of developing a protocol for assessing fine coal technology was to allow research agencies and advisory committees to make timely and effective decisions about projects involving fine coal preparation technology.

It was found that:

- available protocols cannot be adapted to the fine coal situation;
- standard economic evaluation and investment decision methods must allow for comparisons between technologies at different stages of development; and
- three orders of technology assessment requiring increasingly detailed economic interpretation were identified.

It was recommended that a protocol for fine coal technology assessment be developed, using the expertise of international advisors if needed. Also, it was recommended that economic techniques suitable for evaluation of investments having short payback periods be incorporated, and that typical base case information should be assembled on western Canadian coal, as well as its production and transportation.

WESTCOAL Separator

COAL MINING RESEARCH COMPANY, DEVON

During the past decade, spiral separators have been introduced to improve recovery of coal fines during cleaning. However, experience with these devices has shown that they cannot clean western Canadian coal to the degree necessary to optimize production and satisfy out-of-province and export markets. Therefore, the objective of this project is to design and develop a device, known as the WESTCOAL Separator, for coals that are more difficult to clean.

Last year, a basic form for the separator was established by making two design modifications to existing equipment. The modified design used a configuration meant to give a low-density cut point. A field demonstration reduced the clean coal ash content by two per cent.

Subsequent experiments showed that changing the configuration of the main spiral or imposing a vibration to the spiral would not result in improved separation. It was concluded that spiral performance most likely could be improved by making two additional engineering modifications.

The project has been completed.

Publication

Butcher, S.G. 1989. Westcoal Separator. Phase I Report. (Confidential) Coal Mining Research Company.

Electrocoagulation

LUSCAR STERCO (1977) LTD. (EDSON) AND OTHER PARTICIPANTS[1]

Separation of clay from coal fines remains the single most important obstacle to improving the yield efficiency of western Canadian coal preparation plants. Clay and shale particles suspended in process water after coals have been washed are usually removed in mechanical clarifiers to which chemical coagulants have been added. These coagulants are expensive, and process water quality is highly variable and tends to deteriorate with time. This leads to larger dosages of chemicals and rising costs.

An alternative is to use a process called electrocoagulation. In a trial at Luscar Sterco's Coal Valley mine, the process performed well, but it could not compensate for changes in clay chemistry.

[1]Other participants were: Obed Mountain Coal Company Limited and CANMET.

Subsequently, a project was initiated last year, that involved bench-scale electrocoagulation testing by CANMET at the Coal Research Centre, Devon. The experimental work conducted in the first phase of this project determined the optimum operating conditions for the electrocoagulation technology. Initial results indicated that the technology has the potential to be economic, as well as technically effective. It was also determined that the effect of the technology can be extended by treating a relatively clean stream of water before adding it to the contaminated stream. The results indicated that a residual reaction occurred.

Thus, the electrocoagulation technology successfully precipitated particulates over a wide range of conditions. The next step is to obtain capital and operating cost information so the participating mine operators can determine the practical feasibility of using the technology. Therefore, the project will be continued next year.

Publication

Donini, J.C., R.G. Frenette, K.L. Kasperski and S. Kelebek. 1989. Electrocoagulation - Final Report. Prepared by CANMET Coal Research Laboratories on behalf of Luscar Sterco (1977) Ltd.

Coal Agglomeration Process Development

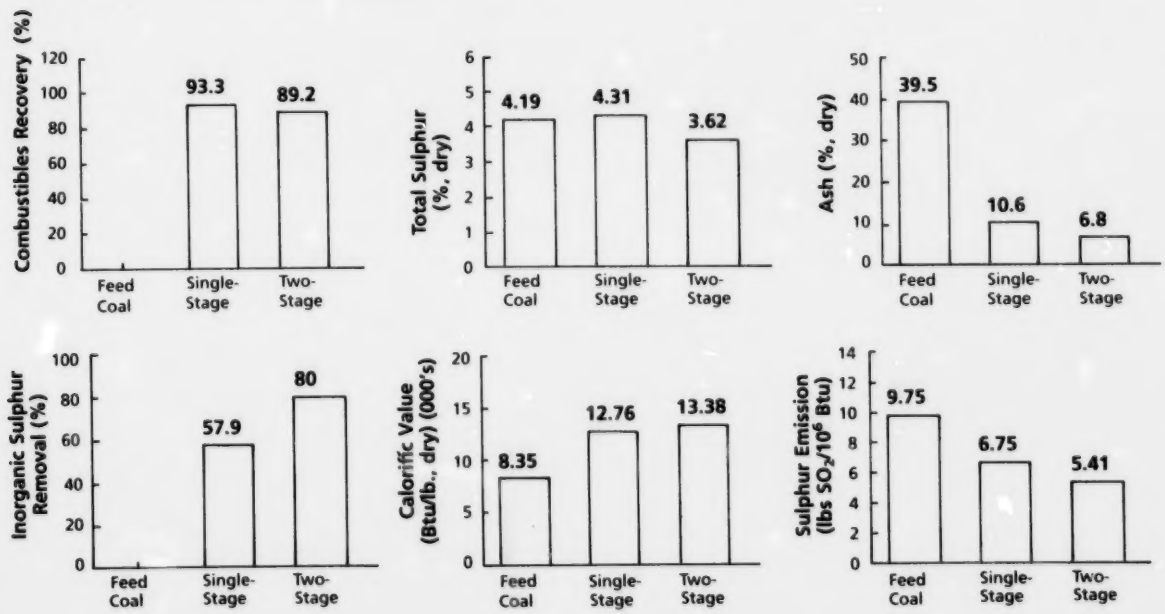
ALBERTA RESEARCH COUNCIL, DEVON

For several years, researchers at the Alberta Research Council, with initial funding from the Office and subsequent funding from the Electric Power Research Institute and other sources, have been developing a method for upgrading low-rank coal, involving a process called oil agglomeration.

By mixing heavy oil or bitumen with coal slurries under controlled conditions, large particles called agglomerates are formed from which much of the undesirable mineral matter present in the original coal has been removed and transferred to the water. This results in products having a higher energy content and lower ash than the parent coals. Subsequent combustion testing showed that agglomerates formed from subbituminous coals displayed excellent combustion characteristics. These results demonstrated that oil agglomeration is a promising upgrading method.

The initial technology has evolved into two processes: AGLOFLOAT, which involves agglomeration followed by froth flotation; and AGFLOTHERM, which includes a thermal treatment step.

Cleaning of Eastern U.S. Coal by Aglofloat Process



In 1987/88, a consortium[1] of 22 companies and institutions began to provide funding for a pilot-scale evaluation of the processes. Since then, a continuous 6-tonne-a-day (250 kg/h) pilot plant and a continuous oil recovery unit were built and made operational. This equipment is being used to evaluate the agglomeration potential of coal samples provided by members of the consortium, and provide data to be used in calculating the process economics of a commercial-scale plant.

Test programs are under way to study low-rank coals, bituminous coal and contaminated soils.

The investigation of low-rank coals includes: increasing the ability to separate mineral matter selectively; understanding the mechanisms responsible for high oil recovery during thermal treatment; the conceptual design of a 250 kg/h de-oiling system for coal/oil feed with a high API oil component; and evaluation of the effects on process economics of improvements in selectivity and de-oiling.

In the bituminous coal studies, batch evaluations are being made of two-stage oil agglomeration on two American coals, and the 250 kg/h agglomeration test facility is being refined and tuned. Also, the performance of a pyrite separator is being tested.

The contaminated soil study includes developing improved methods for cleaning coal-derived tar, slag and coke from soils, and conducting demonstration tests in the 250 kg/h continuous unit with two refuse materials.

Work is continuing on these studies.

Publications

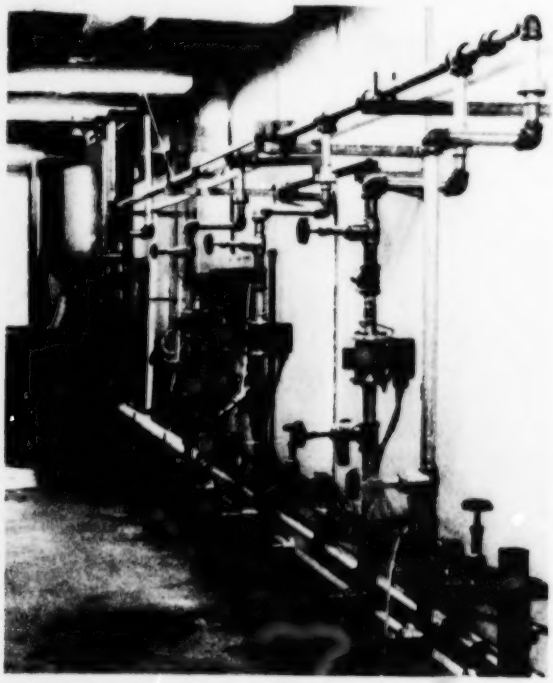
Development of Clean Coal and Clean Soil Technologies Using Advanced Agglomeration Techniques. 1990. Volume 1: Upgrading of Low Rank Coals; The Agflotherm Process. Volume 2: Upgrading of Bituminous Coals; The Agflotherm Process. Volume 3: Soil Cleanup and Hydrocarbon Waste Treatment Process. Alberta Research Council.

[1]The consortium includes: the Electric Power Research Institute, American utility companies, state and federal governments, Canadian oil firms, coal companies, provincial governments, and utility companies.

Particle Distribution in Slurry Flow Through Tees and Manifolds

UNIVERSITY OF ALBERTA (J.H. MASLIYAH), EDMONTON

Two-phase (solid/liquid) flow through a manifold is commonly used in industry to distribute solids to various processing units. This occurs in coal preparation plants as well. Because of differences in inertia between the solid and liquid phases, the solids concentration is not always the same in various branches of a manifold. This means that the relationship between solids concentration in the branches and the main pipe must be studied, and the upstream operating conditions that can affect this relationship must be determined. The objective is to achieve equal distribution of solids in each branch.



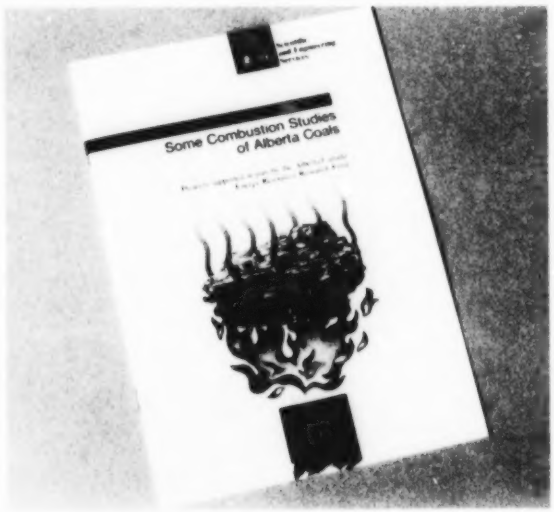
Closed-loop piping arrangement used to study solids concentration in branches of a manifold.

A closed-loop piping arrangement having a manifold with four branches and valves to control slurry flow through the branches was used in this project. Isokinetic and conductivity probes were installed to measure solids concentration upstream and downstream of the branch tees. Initial experiments involving sand/water slurries were conducted, using three configurations of branches: upwards, sideways and downwards.

It was learned that for sand-water slurries, the sideways branch orientation gave the best solids distribution for the range of particle sizes, main pipe velocities and solids concentrations used thus far. The data generated to date were sufficient to develop a model of solids distribution in the branches of the manifold. The empirical model was found to be accurate to within 15 per cent of laboratory observations. This is considered to be adequate for design purposes.

Experiments with polyvinyl chloride particles, having a specific density of 1.2, showed the solids distribution for all three orientations were equally satisfactory. This is significant because the density of polyvinyl chloride is a better approximation to that of coal than is sand, which has a specific gravity of 2.6.

Combustion



Some emerging coal combustion technologies achieve optimum performance from coals having narrowly specified properties. Consequently, coal producers who wish to sell coal to the users of these technologies must be prepared to provide detailed information about the combustion characteristics of their coals. This also implies that coal producers should know how a coal will perform before it is removed from the ground. Therefore, developments in combustion technology have a direct bearing on resource evaluation and coal mining and upgrading.

Furthermore, advances in the science of coal combustion make it necessary to test coals for properties other than those revealed by ultimate and proximate analyses. This means new or improved laboratory-scale combustion testing methods must be developed that not only simulate coal burning in thermal plants but, ideally, can minimize the need for the expensive, full-scale combustion tests used in the past.

Another important function of coal combustion research is to encourage coal producers, coal users and manufacturers of coal-burning equipment to become jointly involved in projects. This can lead to knowledge sharing and the enhancement of technology development in ways that benefit all parties.

With these issues in mind, the Office has supported 18 coal combustion research projects, five of which were active in 1989/90 and are described in the following section.

Also, some completed studies are described in the technology transfer publication, *Some Combustion Studies of Alberta Coals*. It is available from Alberta Energy/Forestry, Lands and Wildlife information centres.

International Energy Agency Coal Combustion Science – Program Extension

NETHERLANDS ENERGY RESEARCH
FOUNDATION ECN, PETTEN

Annex II of the International Energy Agency Combustion Science Research Program involves fundamental studies and a series of investigations using semi-industrial scale coal burners to advance the science of pulverized coal combustion and minimize adverse environmental effects. Facilities of the International Flame Research Foundation (IFRF) at IJmuiden, The Netherlands, are being used.

The principal objective is to provide information that can be used to design burners capable of using a wide range of coals and producing flames having acceptable combustion characteristics, while generating few atmospheric pollutants.

Initially, the Annex II studies were funded jointly by Canada, The Netherlands and the Federal Republic of Germany. Since 1985, the Canadian contribution has been divided among CANMET, the Canadian Electrical Association and the Alberta Office of Coal Research and Technology. The results of the initial research were described in 1988/89.

In October 1988, the other sponsors were joined by Great Britain, and the initial research program was extended.

The earlier research focused on the following mechanisms: nitrogen oxides (NO_x) formation during pulverized coal combustion and opportunities for their reduction through staged combustion; sulphur oxides (SO_x) formation and reduction by the use of direct sorbent injection; transformation of mineral matter during combustion in relation to combustion system slagging, fouling and fly ash emissions; and combustion of various types of coal from several sources.

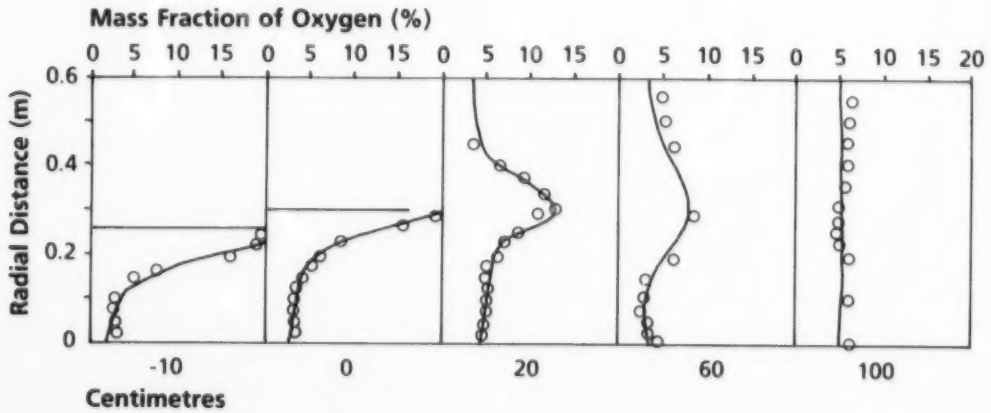
The primary objective of the extended research program will be to gain a better understanding of the influence of coal characteristics on emission levels, using the air-staging and fuel-staging processes developed at IFRF. This research includes the effects of fuel/air mixing and coal blending. Also, mathematical modelling is being used to predict temperature and gas concentrations in the "near-burner" zone. As in previous work, one objective is to include Alberta coals in the test program.

At an Annex II meeting held in May 1989, results of two trials and associated modelling were presented. Numerical modelling of the near-burner zone of three scaled-up versions of the Aerodynamically Air-Staged Burner (AASB) resulted in excellent correlations with the experimental data, particularly in the near-burner zone.

Last year, one fuel-staging trial at a semi-industrial scale was carried out to study the effect of mixing on NO_x reduction. Results from a set of fuel-staging trials showed that NO_x could be reduced from 1 000 ppm to 200 ppm with coal as the staging fuel, and a further reduction to 100 ppm when natural gas was used as the staging fuel.

One semi-industrial scale test was completed on a blend of bituminous and anthracite coals in the AASB. Initial results indicated that NO_x amounts were equivalent to a simple addition of those from the individual coals. Coal characterization trials were started on low-volatile coals. This study is also examining burnout of the final five per cent of the carbon. A co-operative effort with Harwell Laboratories

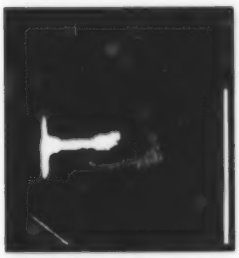
Measured and Predicted Oxygen Mass Fraction – Unstaged Flames



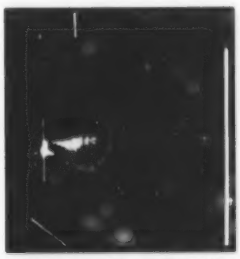
was started to study application of laser techniques for flow visualization and measurement.

A second semi-industrial scale test was completed on a blend of an American high-volatile bituminous coal and Byron Creek low-volatile bituminous coal. This test employed the AASB low-NO_x burner. IFRF scientists presented their research results at a technical seminar for the Alberta coal industry on January 10, 1990 in Edmonton.

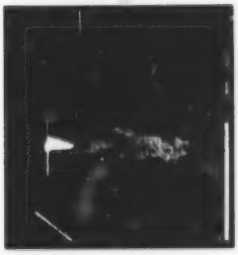
Effect of Primary Swirl
Central Hole Gun - Cold Flows - GP = 130
(Time-averaged photographs)



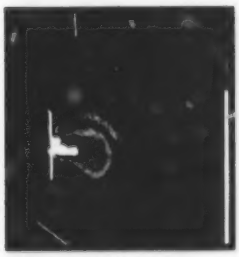
no primary swirl



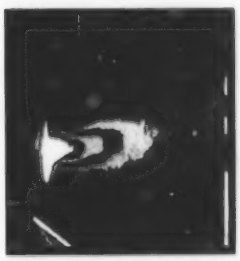
primary swirl co-direction
S_0 = 1.4



no primary swirl



primary swirl contra-direction S_0 = 1.4



with primary swirl
S_0 = 0.0

In these photographs, laser sheet illumination has been used to show the effect of swirl on flow patterns in a burner. Photographs are time-averaged and colour-enhanced by digital techniques.

Publications

Dugue, J., P. Ereaut, H. Horsman and A. Shand. Laser Sheet Visualization in Cold Flows, Gas and Coal Flames in the IFRF Furnace No. 2. Results of the AMT 2 Investigations. IFRF Document F 72/y/19.

Flament, P., S. Bortz and R. Weber. Calcination and Sulphation Studies Under Controlled Conditions for Direct Application to Desulphurisation of Pulverised Coal Flames. Report on the S 2 Experiments, Parts 1 and 2. IFRF Document F 138/a/6.

Flament, P. and M. Morgan. Fundamental and Technical Aspects of SO_2 Capture by Ca-Based Sorbents in Pulverised Coal Combustion. Report on the S 2-4 Study. IFRF Document F 138/a/8.

Knill, K.J. A Review of Fuel Staging in Pulverised Coal Combustion Systems. IFRF Document No. G 13/a/3.

Knill, K.J., J.S.A. Dekker and M.E. Morgan. Evaluation of the Effect of Process Variables on NO_x and Nitrogen Species Reduction in Coal Fuel Staging. IFRF Document F 037/a/20.

Knill, K.J., N. Kimura and J.P. Smart. Effect of Coal Particle Size and Gun Design on NO_x Reduction Using an Aerodynamically Air Staged Burner: Report on the CC 2-2 Trials. IFRF Document F 088/a/6.

Knill, K.J., T.F.J. Maalman and M.E. Morgan. Development of a Combustion Characterization Technique for High-Volatile Bituminous Coals. Report on the CC 4 Trials. IFRF Document F 088/a/10.

Morgan, M.E. and J.S.A. Dekker. Characterization of the Combustion Performance of a Suite of Pulverised Coals. Report on the CC 1 Trials. IFRF Document F 188/a/4.

Morgan, M.E. and J.S.A. Dekker. Effect of Coal Quality on the Performance of Low NO_x Burners. Report of the CC 3 Investigation. IFRF Document F088/a/9.

Smart, J.P., N. Kimura and K.J. Knill. Evaluation of Residence Time and Temperature Distribution in IFRF Furnace #1. Report on the CC 2-1 Investigation. IFRF Document F 088/a/5.

Smart, J.P. and K.J. Knill. Detailed Characterization of the Near Burner Field of a Low NO_x Burner Firing Coal of Two Different Ranks. Report of the CC 2-4 Experiments. IFRF Document F 088/a/8.

J.P. Smart and T.F.J. Maalman. An Analytical Procedure for the Quantitative Determination of NH_3 and HCN in Combustion Systems. IFRF Document F 072/a/16.

J.P. Smart and R. Weber. NO_x Reduction and Burnout Optimisation Using Aerodynamic Air Staging and Air-Staged Precombustors. Report on the AP 16 Trials. IFRF Document F 037/a/18.

Visser, B.M., F. Boysan and R. Weber. Computations of Isothermal Swirling Vortices in the Near Burner Zone. Report on the MMF 1-1 Investigation. IFRF Document F 336/a/9.

Visser, B.M. and M.E. Morgan. Mathematical Modelling of an Entrained Flow Reactor. Report on the CC 5 Investigation. IFRF Document F 088/a/11.

Visser, B.M. and R. Weber. Computations of Swirling Pulverised Coal Flames. Report on the MMF 1-2 and MMF 1-3 Investigations. IFRF Document F 336/a/11.

Visser, B.M. and R. Weber. Computations of Near Burner Zone Properties of Swirling Pulverised Coal Flames. Report on the MMF 2 Investigation. IFRF Document F 336/a/13.

Visser, B.M. and R. Weber. Predictions of Near Burner Zone Properties of Six Swirling Pulverized Coal Flames. Report on the MMF 3 Investigation. IFRF Document F 36/y/14.

Weber, R., J.P. Smart and W.J. Phelan. NO_x Reduction with Coal Firing by Application of Both Internal Air Staging and Fuel Rich Precombustors. Report on the AP 14 Trials. IFRF Document F 037/a/16.

Coal Utilization Program Planning

ALBERTA RESEARCH COUNCIL, DEVON

The services of a combustion engineer from the Alberta Research Council were provided to the Office to oversee research activities under the International Energy Agency (IEA) Annex II project, and to represent the Office during meetings of the Canadian Technical Committee and the IEA Executive Committee for this Annex.

The task also includes technical review of the IEA Annex II Combustion Sciences Research project and transfer of technical information to the Alberta industry, as well as promotion of co-operative research with Japan in coal combustion and gasification.

This year, three draft final project reports were reviewed and comments forwarded to the International Flame Research Foundation (IFRF). Meetings of the Annex I Technical Committee and the Annex II Technical and Executive committees were attended from May 30 to June 1, 1989 in Akersloot, The Netherlands. A report was prepared summarizing presentations and discussions at these meetings. An Annex II meeting was held in Edmonton during the second week of January 1990. IFRF staff gave technical presentations to the Alberta industry as part of these meetings.

Final reports for all projects of the initial Annex II Coal Combustion Sciences program were received and copies submitted to the Office. Coal samples from the Byron Creek coal mine and H.R. Milner Power Station were sent to IFRF for combustion studies of low-volatile coals. Also, Canadian Gasification Technical Committee meetings were attended during the year to report on recent gasification studies at the Alberta Research Council.

This work is continuing.

Publication

Chambers, A.K. 1989. Coal Utilization Program Planning. Alberta Research Council.

Silveston, P.L. (editor). 1989. Coal Conversion Research in Japan - 1988 Report of the Canadian Visiting Team.

A Thermodynamic Model for the Spontaneous Combustion of Coal

UNIVERSITY OF CALGARY (R. PAUL), CALGARY

In recent years, some progress has been made in understanding the causes of spontaneous combustion and in characterizing coals according to their susceptibility to this phenomenon. However, all the conditions existing in a coal storage facility cannot be reproduced in a laboratory. Therefore, the objective of this project was to develop a reliable, thermodynamic model of spontaneous combustion that might be used to predict the likelihood of a self-heating occurrence. Thus, the model could serve as the basis of a monitoring and warning system and could be used to optimize coal transport and storage conditions to reduce the risk of spontaneous combustion.

A model consisting of differential equations was developed to describe exothermic oxidation, oxygen transport, heat of wetting, heat of evaporation, moisture transport and decomposition of peroxides above 70°C. When compared with the results of experimental tests, it was found that the model made predictions about spontaneous combustion that were accurate within a few per cent of the actual experiments.

The research team made seven recommendations to reduce the potential of a spontaneous combustion event in a coal stockpile. They were:

- to prevent the process of exothermic water sorption, operators should avoid storing coal with a moisture content below its equilibrium value;
- operators should not suddenly remove thick layers from stockpiles;
- decreasing stockpile porosity from 20 to 10 per cent should decrease the maximum temperature in a stockpile by 20°C to 40°C, and lower energy losses by approximately 50 per cent during the initial period of storage;
- to reduce oxygen access, it is better to compact the coal than decrease the oxidation rate by using surfactants or coatings;
- to provide useful information for the model calculations, calorimetric experiments on water desorption and peroxides decomposition should be performed;
- it is desirable to perform experiments on water chemisorption and desorption using large samples of coal (10 to 20 kg, at least), instead of using 20- to 100-g samples as done now; and
- a cost analysis should be performed on the storage of coal in large versus small stockpiles.

Sources of Ash Under Controlled Conditions

UNIVERSITY OF CALGARY, (R.C. JOSHI), CALGARY

A travel grant was awarded to Dr. Joshi for a visit to the International Flame Research Foundation (IFRF) at IJmuiden, The Netherlands. The purpose was to investigate the possibility of modifying coal ashes and to determine the sources of variability in fly ash quality.

The visit lasted one month and included attendance at two related meetings and conferences.

The outcome was a proposal submitted to IFRF to study the use of modified Alberta coal ash as a cementatious material for construction or as a replacement for cement in concrete in greater quantities than at present. Also, the study would address the production of specification ash to allow its use in cement concrete without any effect on the air entrainment qualities of concrete.

Some samples of ash routinely collected by IFRF staff were collected for fundamental studies, such as by X-ray and Scanning Electron Microscopic (SEM) analyses. X-ray, SEM and Thermogravimetric analyses were performed on coal-combustion residue samples provided by IFRF. Results of laboratory studies suggest that temperature and residence time affect the properties of these residues.

Publication

Joshi, R.C. and P.V. Sivapullaiah. 1990. Morphological and Mineralogical Characterization of Chars of High-Volatile Bituminous Coal Valley Coal from Alberta. University of Calgary.

Ash Properties of Alberta Coals

ALBERTA RESEARCH COUNCIL, DEVON

It is suspected that an understanding of the ash properties of Alberta coals may lead to a marketing advantage in an increasingly competitive marketplace. Also, a better knowledge of the transformations that Alberta coals undergo when they are burned may result in new commercial uses for the resulting ash.

Thus, coal and ash samples obtained from several locations within the Unit #5 boiler at Alberta Power's Battle River generating station were analysed for various properties. Also, a literature study was undertaken to determine which ash properties are most important. As well, discussions were held with Dr. Joshi of the University of Calgary about mutual collaboration on uses for coal ash.

The 3 kg/h combustor, used in other coal combustion studies at the Alberta Research Council, was fitted with a swirl burner and tested at combustion temperatures of 1 500°C. Ash samples from this unit were analysed and compared to the utility boiler samples.

This work will continue in 1990/91.

Liquefaction

During the next 30 years, production of conventional crude oil from Alberta's established oil fields is expected to decline well below current levels. The rate of decline will depend on a number of factors, such as world oil prices and demand, but eventually it will become necessary to produce more synthetic crude oil from Alberta's oil sands, heavy oil and coal. Although the economics of producing oil in this manner are unattractive as long as oil prices are depressed, abundant quantities of raw materials are readily available for extraction whenever the economics become more favourable. For instance, Alberta's proven reserves of subbituminous coals could provide enough synthetic crude oil to satisfy domestic consumption for at least the next century, assuming a suitable and economic liquefaction process can be developed to convert coal to petroleum substitutes.

One conversion concept that is showing some promise, and has been studied extensively in Alberta, involves co-processing of coal and heavy oil or bitumen. This process not only provides a method for producing synthetic crude oil from coal, but may also prove to be useful in upgrading heavy oil. This and other potential liquefaction processes are under development, some of which may involve less severe reaction conditions than used elsewhere. Also, methods of analysing the quality of liquefaction products are being actively investigated in Alberta. Furthermore, the level of liquefaction research in Alberta has led to considerable collaboration among the various participants at Alberta Research Council, the University of Alberta and in private industry.

Thus far, the Office has supported 21 coal liquefaction research projects, some of which are multi-year, major efforts. Seven projects, active this past year, are described in the following section.

Also, the Office has published two technology transfer booklets on coal liquefaction. They are: *Co-processing Studies of Alberta Subbituminous Coals,* and *Methods for Producing Liquid Hydrocarbons from Coal.* Both are available from Alberta Energy/Forestry, Lands and Wildlife information centres.

Co-processing Process Development

CANADIAN ENERGY DEVELOPMENTS INC., EDMONTON

Canadian Energy Developments Inc. (CED) is developing a process to make synthetic crude oil from subbituminous coal and bitumen. This process, known as co-processing, not only provides a method for producing synthetic crude oil from coal, but may also be useful in upgrading heavy oil.

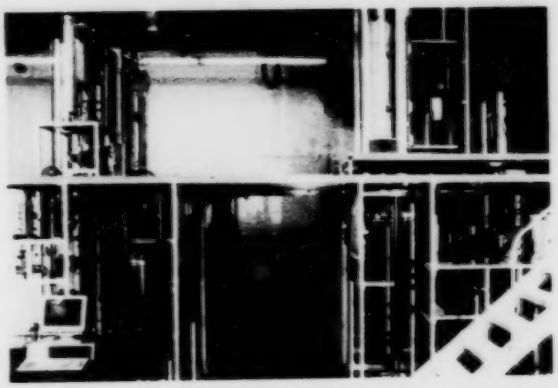
The overall objective of the company is to design, construct and operate a commercial-scale, co-processing upgrader in Alberta in the 1990s.

Currently, the company is simultaneously developing two co-processing schemes. One of these, known as PYROSOL, is a low-severity, two-stage process. It comprises mild hydrogenation and coking in a pressurized delayed coker under a hydrogen atmosphere.

The synthetic crude product from the PYROSOL process contains approximately 10 per cent naphtha, 60 per cent middle distillate and 30 per cent heavy distillate. It has the potential to be a premium product because it contains substantial quantities of middle distillate from which aviation and diesel fuels are made.

The second co-processing scheme, the CCLC process, involves coal solvolysis in a heavy oil slurrying medium followed by moderately severe hydrogenation of the solubilized coal and heavy oil.

The synthetic crude from the CCLC process is a light distillate containing approximately 35 per cent naphtha, 45 per cent middle distillate and 20 per cent heavy distillate. The product is substantially lighter than that produced by the oil sands plants in Fort McMurray.



The PYROSOL and CCLC coal/heavy oil co-processing methods of Canadian Energy Developments Inc. are being tested and developed on this 250 kg-per-day process demonstration unit.

Interest in these processes, and co-processing in general, stems from the fact that use of low-cost coal lowers the feedstock cost and the overall production costs of these upgrading schemes below those used to upgrade heavy oil or bitumen alone.

Since this process development project began in 1986, a 2 kg/h, two-stage hydrogenation bench-scale unit (BSU) and a 1.3 L pressurized delayed hydrocoker have been used to conduct operating-severity studies. In these studies, hydrogenation pressure, temperature and reactor residence time were varied to control the distillable oil yield and maintain a high level of pitch conversion.

Also, a 250-kg-per-day continuous process demonstration unit (PDU) was commissioned to allow long duration, continuous studies to be made on a larger scale.

This year, a hydrogen recycle system (compressor and preheater) was added to the PDU to increase superficial gas velocities inside the reactors. Since the recycle system was commissioned, the PDU has been operated continuously for more than 400 hours without any settling of solids at superficial gas velocities that were approximately three times those of previous tests. These tests helped to confirm some of the advantages of counterflow reactor (CFR) technology over co-current reactor designs. The CFR technology is being developed jointly by CED and Gesellschaft für Kohleverflüssigung m.b.H. (GfK).

The experiments undertaken this year are a continuation of previous work, which is expected to be concluded next year.

Molecular Interactions Between Heavy Oil and Coal Species During Co-processing

UNIVERSITY OF CALGARY (P. CLARK), CALGARY

Heavy oils used in coal/bitumen co-processing schemes are rich in asphaltenic material and reactive sulphur compounds. These oils contain three to six per cent sulphur by weight, combined in a multitude of compounds. These compounds are likely to react with the radical species produced when coal is solubilized, which could result in undesirable products. Therefore, the objective of this project is to study these reactions and determine which process conditions avoid or minimize the formation of unwanted substances.

Although Alberta heavy oils contain a wide array of sulphur compounds, they can be classified in three main types: aliphatic thioethers, aromatic thioethers and condensed aromatic sulphur heterocycles. Chemicals representing each class were reacted with three chemicals having molecular structures commonly found in coal, namely hexadecane, naphthalene and tetralin. These reactions were carried out in a small (300 mL) autoclave, under thermal, thermal/hydrogen, and thermal/hydrogen/catalytic process conditions.

It was concluded that model compounds interact to give undesirable products in the absence of an efficient hydrogen supply and a suitable catalyst. Aliphatic thioether and oxygen-containing compounds were particularly reactive and produced complex substances that were unsuitable for upgrading to refinery-acceptable feedstocks. The addition of coal to model compounds in some experiments increased the degree of reaction drastically and promoted the formation of complex materials.

There was evidence, however, that high-activity catalysts could be useful in producing substances that are more easily refined. Alumina-supported nickel/cobalt catalysts, dispersed through the solubilized coal/bitumen mixture, produced the best yield of distillates when the mixture was heated to 425°C in the presence of hydrogen.

Combined Processing of Coal, Heavy Oil and Natural Gas

UNIVERSITY OF ALBERTA (M.R. GRAY), EDMONTON

One of the major costs of coal/heavy oil co-processing is incurred during the production of gaseous hydrogen, which is currently obtained by steam reforming natural gas. Although hydrogen gas is important because it suppresses the formation of coke in co-processing reactors, and helps to upgrade the liquids from coal and heavy oil by raising the

hydrogen:carbon ratio, a less-expensive source of hydrogen would enhance significantly the economics of co-processing.

In a previous study funded by the Office, the use of high-pressure natural gas was used directly as the hydrogenation agent. In the presence of tetralin and Fe_2O_3 catalyst, the conversion of Highvale subbituminous coal to toluene-soluble products was equal to or higher than that from hydrogen gas liquefaction. Thus, the substitution of methane (natural gas) for hydrogen would make co-processing more economically attractive if comparable product quality and yield can be achieved.

This year, a new project was initiated to determine the yields and product qualities from the continued processing of coal, heavy oil and natural gas, and provide the data necessary to evaluate the feasibility of the combined processing concept.

A set of experiments using Cold Lake bitumen and Highvale coal was completed. The bitumen content of the feed was varied from 5 to 30 per cent, and the reactions were carried out at 430°C under methane pressures of 13 to 17 MPa. Poor yields of liquid products were obtained, with the principal product being a tarry slurry. Another set of experiments under less severe conditions is planned.

Co-processing of Coal and Bitumen with Molten Halide Catalysts

UNIVERSITY OF CALGARY (A. CHAKMA), CALGARY

In this project, the principal objective is to liquefy an Alberta subbituminous coal and simultaneously upgrade bitumen in the presence of molten halide catalysts under hydrogen pressure. It is believed this might increase liquid yields, and decrease the asphaltene fraction and increase the maltene fraction of the products.

Thus far, the experimental apparatus was commissioned and experimentation commenced. Some problems with controlling the heating system were encountered, but these have been overcome. Several metal chlorides and their mixtures were tested. In total, approximately 50 experiments are planned at 400°C in the presence of hydrogen.

Product and Process Characterization

ALBERTA RESEARCH COUNCIL, DEVON

This project aims to develop an understanding of the chemical changes that occur when coal and bitumen react in co-processing schemes. This should help researchers understand the effects of process changes on the products. It involves analytical characterization of co-processing products to determine better the reaction pathway when coal and bitumen are co-processed to produce synthetic crudes.

A budget cut soon after this project was initiated severely curtailed progress. Nevertheless, samples of co-processed products were evaluated by Nuclear Magnetic Resonance for Cetane Index, resin samples obtained from the bench-unit experiments of Canadian Energy Developments Inc. were analysed and compared, samples of secondary products (middle distillate fractions) were submitted for Field Ionization Mass spectrometer analysis, and detailed analysis of high molecular weight products was reported at meetings and received keen interest.

This analytical work will continue next year and will be accompanied by the production of a laboratory guide to coal conversion analysis. The guide will summarize the extensive work undertaken in this field over the past five years.

Publications

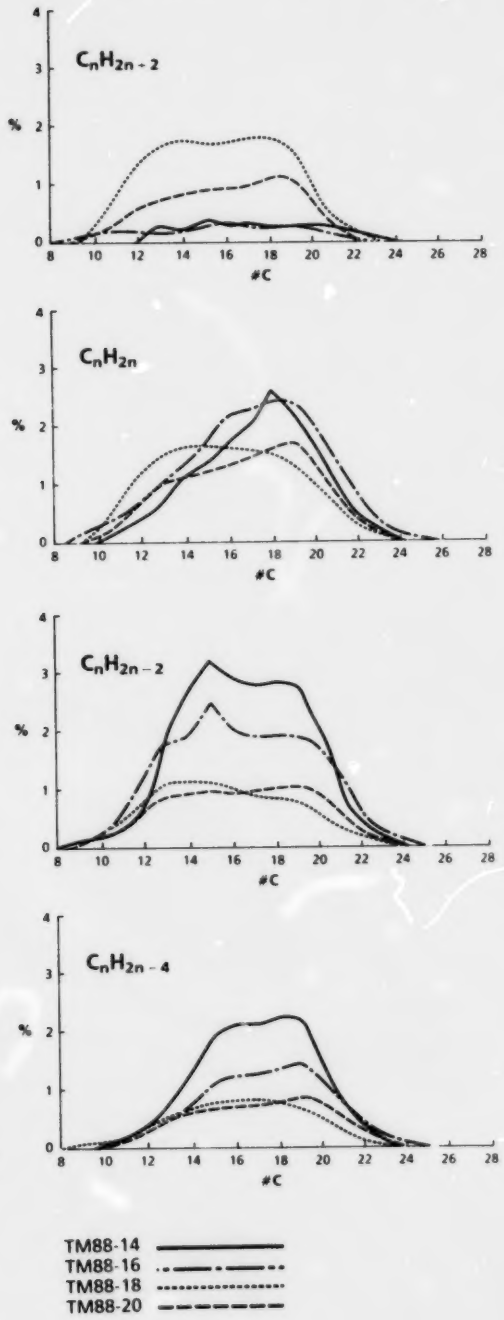
Selucky, M.L., D. Bizzotto and T. Manske. 1989. Detailed Analysis of Feed and Product Asphaltenes in Products from Coal Bitumen Co-Processing. Presentation at the American Chemical Society Spring Symposium, Dallas, Texas.

Selucky, M.L., D. Bizzotto and T. Manske. 1989. Detailed Analysis of Feed and Product Asphaltenes in Products from Coal Bitumen Co-processing. American Chemical Society, Petroleum Chemistry Division, Preprints, B4 (2) 214.

Selucky, M.L., R. Wasel, B. Rawluk and T. Taerum. 1989. Application of 1H and 13C NMR for the Evaluation of Cetane Index of Middle Distillates. Presentation at the Canadian General Standards Board Meeting, Edmonton, Alberta.

Selucky, M.L., R. Wasel, B. Rebus and T. Taerum. 1989. Application of 13C and 1H NMR for Evaluation of Cetane Rating of Middle Distillates. Presentation at the Confab '89 Conference, Laramie, Wyoming.

Distribution of Saturates in Various Middle Distillates, as Measured by Field Ionization Mass Spectrometry



Coal/Heavy Oil Co-processing Management Committee

In August 1988, a management committee[1] was formed to assess the rationale and need for further development of technology suitable for co-processing of coal and heavy oil.

Several feasibility studies had indicated that co-processing is a less expensive method than direct liquefaction for producing synthetic fuels from coal, and it might even be an alternative to the current method for upgrading heavy oil/bitumen to synthetic crude oils. Therefore, the technical committee initiated a two-phase investigation to identify the relative merits and economics of coal/oil co-processing compared to heavy oil upgrading. The study is also examining strategies affecting commercial development of co-processing technologies in Alberta.

The first phase of the project was completed this year. Under the leadership of the Alberta Oil Sands Technology and Research Authority (AOSTRA), and with financial contributions from some of the technical committee members, it was found that the economics of co-processing are essentially equivalent to those of heavy oil upgrading at today's feedstock prices. The strategic factors that can have a significant effect on the commercial development of co-processing are: feedstocks; plant location; infrastructure; technology and plant capacity.

The second phase of the work will be conducted in 1990/91.

[1]Current members of the management committee are: Canadian Occidental Petroleum Ltd., Alberta Power Limited, Gulf Canada Resources Limited, Husky Oil Operations Ltd., Shell Canada Limited, TransAlta Utilities Corporation, Amoco Canada Petroleum Company Ltd., Mitsui SRC Development Co. Ltd., Saskatchewan Energy and Mines, Alberta Oil Sands Technology and Research Authority, and the Alberta Office of Coal Research and Technology.

Specialty Chemicals from Coal-Derived Liquids

ALBERTA RESEARCH COUNCIL, DEVON

It has been found that coal-derived liquids can be an excellent source of carbon and polycondensed aromatic and nitrogen-containing compounds. In particular, the residual fraction from coal liquids can be an ideal feedstock for carbon fibre products, as long as favourable conditions are provided for fibre initiation, a state known as the "isotropic" or "mesophase." Also, coal liquids can be used as feedstocks for high-value fine chemicals, monomers and pharmaceutical intermediates.

Thus, a project was initiated this year to develop processes for making general purpose carbon fibres from coal-derived pitch, and to investigate the production of fine chemicals from coal-derived distillates.

Thermally treated samples of coal-derived liquids and co-processing pitches were examined by Scanning Electron Microscopy and polarized light to identify the state of porosity and mesophase development. It was found that the examined samples should be suitable for carbon fibre production. A carbon fibre production apparatus has been designed, and it will be built and tested in 1990/91. Oxidation of side chains was performed to produce carboxyl groups on aromatic rings present in coal-derived liquids.

Polarized light micrograph of mesophase formed from coal-derived pitch.

Isotopic Studies of Coal/Bitumen Co-processing Schemes

UNIVERSITY OF ALBERTA (K. MUEHLENBACHS), EDMONTON

An analytical technique, known as isotope mass balance, can measure the ratio of carbon-13 to carbon-12 isotopes in coal and bitumen. This allows researchers to differentiate between the carbon derived from coal and that derived from bitumen in the products of coal/bitumen co-processing.

Thus, in 1987/88, a project was begun as a co-operative effort involving researchers at the University of Alberta and the Alberta Research Council. In it, the isotope mass balance technique is used to determine optimum coal/bitumen reaction conditions. Also, the technique is being used to evaluate the results of secondary upgrading schemes aimed at converting co-processing products into synthetic crude oils suitable as feedstocks for conventional refineries.

The results of carbon ratio studies were reported in 1988/89.

This year, hydrogen isotope effects were studied. The researchers co-operated with the Kentucky Energy Cabinet in applying the isotopic mass balance technique in co-processing experiments.

Also, the continuous combustion train, meant to speed up the analysis, was not as precise and reproducible as the single closed-tube combustion method used previously. The researchers reported that the natural variance in abundance of the carbon-13 isotope in coal and bitumen appears to be a good tool to monitor co-processing.

Publications

Muehlenbachs, K. 1990. Isotopic Studies of Coal/Bitumen Co-processing Schemes, Final Report. University of Alberta.

Muehlenbachs, K., J.G. Steer, A. Hogg, T. Ohuchi and G. Beaulieu. 1988. Natural Variations of ^{13}C Abundance in Coal and Bitumen as a Tool to Monitor Co-processing. Proceedings of the 195th American Chemical Society National Meeting and 3rd Chemical Congress of North America, Toronto, Ontario.

Ohuchi, T., M. Bombin, J. Wilson and K. Muehlenbachs. 1988. Catalytic Hydrotreatment of the Products from the First Stage of Coal/Bitumen Co-processing. Proceedings of the 38th Canadian Chemical Engineering Conference, Edmonton, Alberta.

Ohuchi, T., J.G. Steer, K. Muehlenbachs and D. Carson. 1987. The Influence of Iron Based Catalyst on Coal Solubilization as Determined by ^{13}C Mass Balance Calculations. Proceedings of the 1987 International Conference on Coal Science, Maastricht, The Netherlands.

Steer, J.G., T. Ohuchi and K. Muehlenbachs. 1987. Efficacy of Coal-Bitumen Co-processing as Determined by Isotopic Mass Balance Calculations. Fuel Processing Technology. 15: 429-438.

Gasification

Because coal is used to produce more than 90 per cent of Alberta's electrical power, the economic and environmental importance of efficient power generation from coal will be crucial to Alberta's development for the foreseeable future. Integrated Coal Gasification Combined Cycle (IGCC) is regarded by the power-generation industry as the technology of choice for electrical power production from coal. Thus, IGCC is being seriously considered by industry because it is economically competitive with conventional coal-combustion systems and it has demonstrated unparalleled performance in emission control. IGCC offers the ability to reduce NO_x and SO_x emissions below levels currently required by regulation or recommended by guidelines. Also, the increased efficiency of IGCC relative to other coal-based technologies results in approximately 15 to 20 per cent less carbon dioxide production per unit of electrical output. Furthermore, current IGCC technology can permit essentially complete removal of CO_2 from the stack gas, if required.

Alberta's coals are unique in that they have a low-sulphur content and high reactivity. Most current coal-utilization technologies, however, have been developed for coals that contain more sulphur and are less reactive.

Therefore, 11 research projects have been initiated thus far to study the gasification properties of Alberta coals and to quantify their behaviour when used in several existing IGCC systems.

Two of these projects were active in 1989/90.

Gasification projects completed thus far are described in two technology transfer booklets. They are: *Gasification of Western Canadian Coals,* and *Gasification of Alberta Coals.* Also, the publication *Development of Clean Coal Technologies for Alberta* contains information on Integrated Gasification Combined Cycle processes. All three publications are available from Alberta Energy/Forestry, Lands and Wildlife information centres in Calgary and Edmonton.

Canadian Coal Gasification Technical Committee

In 1987, a consortium[1] of sponsors, headed by TransAlta Utilities Corporation of Calgary, funded an investigation of coal gasification technologies and applications. This included determining the potential of using Alberta coal in existing or emerging systems.

The study concluded that Integrated Gasification Combined Cycle (IGCC) systems now under development are demonstrating several advantages over current, coal-fired thermal technology for electricity generation. In particular, IGCC is considered the front runner of various proposed "clean coal" technologies intended to produce substantially fewer air emissions than conventional, thermal, electricity-generating systems. Although experience with large-scale IGCC systems is limited, all indications suggest they produce considerably lower NO_x and SO_x emissions than do conventional coal combustion facilities. Also, particulates are reduced significantly in comparison with conventional thermal plants. In addition, IGCC plants have higher thermal efficiencies than coal combustion plants, leading to lower carbon dioxide emissions.

Therefore, it was recommended that Alberta coal producers and researchers should become actively involved in IGCC developments. Subsequently, the Canadian Coal Gasification Technical Committee[2] was formed to oversee and fund coal gasification projects comprising a

[1]The consortium comprised: TransAlta Utilities Corporation (with Monenco Consultants Limited as the principal subcontractor), Alberta Power Limited, Luscar Ltd., Saskatchewan Power Corporation, Atlantic Coal Institute and the Alberta Office of Coal Research and Technology.

[2]As of March 31 1990, participants in the Canadian Coal Gasification Technical Committee were: TransAlta Utilities Corporation, Edmonton Power Limited, Shell Canada Limited, Monenco Consultants Limited, Alberta Power Limited, The Coal Association of Canada, Nova Scotia Department of Mines and Energy, Saskatchewan Department of Energy and Mines, CANMET, and the Alberta Office of Coal Research and Technology assisted by the Alberta Research Council.

multi-year research program. The objectives of this program are:

- to design and build a 100 MW (electrical) prototype IGCC plant in Canada by 1994;
- to establish and standardize coal gasification testing methods for Canadian laboratories; and
- to facilitate performance evaluations of Canadian coals in various coal gasification technologies.

The program has been divided into five major elements. They are:

- Technology assessment;
- Coal characterization;
- Exploratory experimentation;
- Engineering systems design; and
- Applications research.

Projects associated with these elements are to focus on each of the major steps involved in gasification, from preparing coal as feedstock to emission control.

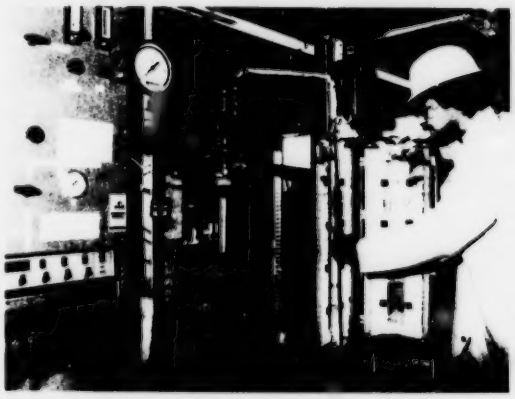
Thus far, four projects have been funded by industry and the Office. Also, five gasification research projects carried out at the Alberta Research Council and used to support technical committee projects have been completed, and another is continuing. In addition, other members of the Canadian Coal Gasification Technical Committee participated in a coal characterization study last year. It involved analysis and testing of coals from British Columbia, Alberta, Saskatchewan and Nova Scotia to enable predictions of coal behaviour under conditions encountered in various gasification reactors. Approximately 30 parameters were studied to establish basic composition and gasification characteristics of 20 coals. Testing was carried out by the Alberta Research Council and the Geological Survey of Canada, under the leadership of CANMET.

Test results pertaining to western coal were reported in *Databank of Western Canadian Coals for Gasification,* available from CANMET.

Gasification Properties of Alberta Coals, II

ALBERTA RESEARCH COUNCIL, DEVON

Last year, a staff member of Alberta Research Council conducted experiments on a state-of-the-art entrained-flow gasifier at Brigham Young University in Utah. In the course of this investigation, some work was done on the potential for hot gas sulphur capture using limestone injection into the reactor. Coal from the Highvale mine was used. This led to additional work on sorbent injection this year, with the objective of developing an inexpensive disposable sorbent for use in removal of pollutant species from gasifiers operating with low-sulphur Alberta coals. This could improve considerably the efficiency and economics of coal gasification processes. The principal pollutants of interest are hydrogen sulphide, carbonyl sulphide and ammonia. This work was carried out in co-operation with the Canada Centre for Mineral and Energy Technology (CANMET).



Gasifier Sorbent Unit at Alberta Research Council.

A literature review was completed on sorbent capture of H_2S. Several potential sorbents were identified, and two samples were obtained. A new reactor and a gas-mixing system were installed for the sorbent evaluation experiments, and modifications to a drop-tube combustor were completed. Pressure testing and initial commissioning experiments were completed for the new reactor.

Pilot-scale sorbent evaluation experiments will be conducted in 1990/91.

Publications

Kovacik, G., B. Ozum and A.K. Chambers. 1989. Gasification Properties of Alberta Coals. Alberta Research Council.

Kovacik, G., A.K. Chambers and B. Ozum. 1989. Gasification Characterization of Alberta Coals. Alberta Research Council.

Kovacik, G., M. Oguztoreli, A.K. Chambers and B. Ozum. 1989. Equilibrium Calculations in Coal Gasification. Alberta Research Council. (Submitted to International Journal of Hydrogen).

Kovacik, G., A.K. Chambers and B. Ozum. 1988. Staff Training: Gasification Process Research. Alberta Research Council.

Kovacik. G., A.K. Chambers and B. Ozum. 1988. Study of Fundamental Gasification Properties of Alberta Coals. Alberta Research Council.

Kovacik, G., A.K. Chambers and B. Ozum. 1988. Gasification Characterization of Alberta Coals. Alberta Research Council.

Kovacik, G., A.K. Chambers and B. Ozum. 1988. Laboratory-Scale Facilities to Study Gasification Properties of Alberta Coals. Alberta Research Council.

IGCC Utility Applications

TRANSALTA UTILITIES CORPORATION (CALGARY) AND OTHER PARTICIPANTS[1]

While it is recognized by the power-generation industry that IGCC technology used with coal will produce minimal amounts of emissions, the technology is not yet mature; additional development of the concept is required to realize its full economic potential. Thus, it was decided an important step in promoting this technology in Canada would be a detailed economic screening study to evaluate the costs of building and operating various IGCC processes at specific locations in Canada. The Canadian Electrical Association was the lead sponsoring agency in this investigation.

Three case studies involving three coals were selected for investigation. They were:

- a nominal 250 MW IGCC unit for Nova Scotia Power Corporation at Point Aconi, using high-ash, high-sulphur, bituminous Prince coal (Case A);
- a nominal 750 MW IGCC unit for Ontario Hydro at Wesleyville, using a high-quality bituminous coal from the United States (Case B); and
- a nominal 500 MW mine-mouth IGCC unit for TransAlta Utilities Corporation, using low-rank subbituminous Blackfoot coal (Case C).

Five gasification technologies were evaluated for each of the three case studies, and some were selected for further evaluation, in consultation with the host utility. The Shell technology was selected for Case A; the Texaco technology for Case B, and the Dow technology for Case C. It was stressed that as gasification technologies develop and utility needs change, the preferred technology may also change.

Performance estimates for each of the three case studies were prepared. They confirmed that all the IGCC technologies studied have high efficiencies and low emissions of NO_x, SO_x and particulates.

In addition, the ash is converted to an inert slag which is suitable for sale as construction aggregate.

Subsequent to the evaluation of the technologies and the preparation of cost estimates, project schedules and implementation plans were developed for each case study. Each implementation plan included requirements for plant staffing and construction manpower, transportation of major equipment, and the use of modules.

The study, which was undertaken by Bechtel Canada Inc., concluded that IGCC appears to be a technically, environmentally, and economically promising technology for near-term commercial applications.

It was further concluded that additional research and development could reduce capital costs and improve plant performance. Potential improvements in the gas turbine design, the air separation unit design, and the gasification heat recovery unit offer potential cost savings. It was recommended that additional research should include coal tests, continued review of gasification technologies, analysis of heat recovery unit designs, emission reduction studies, evaluation of markets for by-products, and a review of developments in hot gas cleanup technology.

[1]Other participants besides TransAlta Utilities and the Canadian Electrical Association were: Alberta Power Limited, Esso Resources Canada Limited and the Ontario Ministry of Energy.

Transportation

Except for subbituminous coal, which is consumed in Alberta at mine-mouth thermal power plants, Alberta's other coal products must be shipped long distances to market. Therefore, transportation costs make a significant contribution to the delivered costs of Alberta coals. For example, transportation by rail accounts for 35 per cent of all the costs to mine, clean and deliver Alberta coals to Pacific ports.

As an alternative to rail haul, the concept of moving coal slurries to market in a pipeline has been the subject of two major feasibility studies in Alberta since 1980. Each investigation indicated that, within certain limits, coal pipelining to the west coast or Ontario is viable.

Given the current priority of reducing the delivered cost of Alberta coal in Ontario, five additional coal pipelining investigations were carried out in recent years. One is described in the following section, and one additional project is found in the Western Canadian Low-Sulphur Coal to Ontario section.

Coal Slurry Technology

SALZGITTER INDUSTRIEBAU GmbH,
FEDERAL REPUBLIC OF GERMANY

In this collaborative[1] project, an investigation is being made of the technical and economic feasibility of producing, transporting by pipeline and burning a coal-water slurry fuel made from Alberta coal using Salzgitter's DENSECOAL process. This is an alternative transportation scheme for lowering the delivered cost of coal in Ontario and other markets.

In previous years, it was found that coal slurries made from medium-volatile Alberta coal and a blend of medium-volatile and high-volatile Alberta coals exhibited stable behaviour and could be pumped long distances. Some difficulties arose, however, when combustion tests were performed. The results of these tests were unsatisfactory. It was found last year that atomization of the slurry was critical for acceptable combustion. It was suggested that changes be made to improve the spray quality of the slurries, and a higher proportion of more volatile coal be incorporated into the coal blend.

This year, the combustion program was redesigned and the slurries were agitated during transport to avoid settling. Combustion testing was performed by a private firm in California. Both the atomization and combustion tests were successful. Using these test results, computer modelling was carried out to determine the degree of "derating" in boiler performance caused by the use of slurries in place of fuel oil. Modelling was also used to generate boiler conversion costs. Capital and operating costs were estimated for two sizes of DENSECOAL plants: 1 million tonnes and two million tonnes a year.

Trans Mountain Pipe Line Company Ltd. and Interprovincial Pipe Line Limited, in co-operation with Salzgitter, produced capital and operating costs for the western pipeline route to Pacific markets and the eastern pipeline route to the Ontario market, respectively. Salzgitter provided additional engineering data produced through comprehensive testing in Germany.

Additional combustion testing is planned for 1990/91.

[1]Participants were: Ontario Hydro, Trans Mountain Pipe Line Company Ltd., Interprovincial Pipe Line Limited, several coal producers, Bundesministerium für Forschung und Technologie (Federal Republic of Germany), and CANMET.

Enhanced Oil Recovery

Coal Use for Heavy Oil Recovery Technical Committee

In 1985/86, the Office and several companies financed a study entitled *Fuel Options for Enhanced Hydrocarbon Recovery*. The investigation concluded that it was cost-effective for oil companies to use coal instead of natural gas to generate steam needed for enhanced recovery of heavy oil. The study also noted that to use coal successfully in heavy oil recovery schemes, a specially designed, pulverized coal-fired boiler was needed.

Subsequently, the Coal Use for Heavy Oil Recovery Technical Committee[1] was formed. It proposed a four-stage development program as the next step in using coal for heavy oil recovery. In the first stage of the program, two boiler manufacturers proposed designs for an innovative coal-fired steam generator. In the second stage, Combustion Engineering prepared an engineering design, which was described last year in the project Coal-Fired Steam Injection Boiler. Concurrently, the committee agreed to investigate the suitability of using the Low NO_x/SO_x Burner (LNSB) system being developed by TransAlta Resources Investment Corporation. This led to two projects. One, Application of the LNS Burner to an Oil Field Steam Generator, was initiated and concluded last year. The other, LNSB Steam Generator Demonstration, continued this year.

Added this year was a study of the merits of using slurry pipelining systems being developed by Unocal Canada Limited to convey coal-condensate or coal-oil mixtures from Alberta coal mines to sites of heavy oil extraction operations. Thus far, the Alberta Office of Coal Research and Technology has participated financially in seven research projects related to the use of coal for steam raising in heavy oil recovery.

Based on progress to date, the committee anticipates the next phases of work could include scaleup to commercial scale of the Combustion Engineering boiler, as well as commercial-scale demonstrations of the Low NO_x/SO_x Burner and the Unocal coal slurry systems. Also, the committee is involved in studies of emission control technologies that are suitable for low-sulphur Alberta coals.

This development program is anticipated to cost over $10 million. The potential benefits, however, could be several times this amount in terms of domestic coal sales and lower steam production costs.

Office publications, *Opportunities to Use Coal in Enhanced Oil Recovery*, and *Development of a Coal-Fired Boiler for Steam Injection in Heavy Oil Recovery* describe progress thus far. In addition, some details about the Low NO_x/SO_x Burner are included in the publication, *Development of Clean Coal Technologies for Alberta*. All three are available from the Alberta Energy/Forestry, Lands and Wildlife information centres.

[1]Current committee members are: Esso Resources Canada Limited, Fording Coal Limited, Luscar Ltd., TransAlta Utilities Corporation, Alberta Power Limited, Shell Canada Limited, Unocal Canada Limited, Energy, Mines and Resources Canada, Alberta Oil Sands Technology and Research Authority, Alberta Office of Coal Research and Technology, and other observers.

Delta Projects Inc. provides co-ordination and promotional services to the committee.

Economics of Coal Use for Heavy Oil Recovery

SHELL CANADA LIMITED, CALGARY

Members of the Coal Use for Heavy Oil Recovery Technical Committee[1] funded a study this year to evaluate the cost differential between using coal and natural gas for steam raising at Alberta in situ heavy oil extraction projects.

An economic model was developed for two process configurations, using the 190 GJ/h (180 million BTU/hr.) steam generators commonly used in the oilfield. One configuration involved six steam generators in a row (commonly referred to as a "six-pack"), while the other used three six-packs.

The economics were based on the transportation of coal from any of three selected coal resource areas (Highvale, Camrose-Riley or Obed) to either the Peace River oil sands area or the Cold Lake heavy oil area. Transportation costs were based on information provided by rail and truck operators, and reflect anticipated commercial rates.

The following costs were developed for the model at both process volumes:

- capital costs for a coal-fired boiler plant, including the boilers, buildings, coal unloading and handling systems, ash-handling equipment and other peripherals;
- capital costs for a gas-fired boiler plant, including the boilers, buildings and other peripherals;
- purchase and transportation costs for both coal and natural gas; and
- applicable operating costs for the coal- and gas-fired steam generators. This included fuel, maintenance, operating staff, boiler feed water treatment, lime, ash disposal and other costs.

The study assumed the project would start up in 1995, and found that the capital cost (in 1989 dollars) of the coal-fired steam generators and related facilities could be between 3.5 and 5 times greater than that of natural gas-fired steam generators. The economic evaluation concluded, however, that coal-fired steam generation could be economically attractive over the next 25 years because natural gas prices were expected to rise faster than those of coal. The economic model can be used to evaluate site-specific fuel price and cost projections for individual heavy oil projects.

[1]Study participants were: Alberta Power Limited, Esso Resources Canada Limited, Fording Coal Limited, Luscar Ltd., TransAlta Utilities Corporation, Shell Canada Limited, Unocal Canada Limited, and the Alberta Office of Coal Research and Technology.

LNS Burner Steam Generator Demonstration

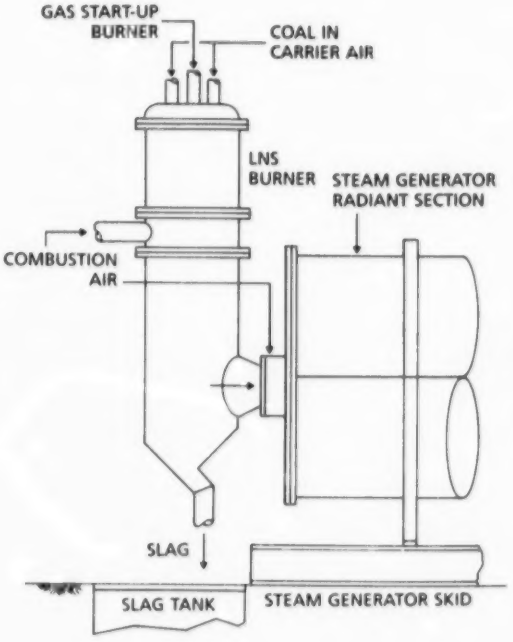
TRANSALTA RESOURCES INVESTMENT CORPORATION AND ESSO RESOURCES CANADA LIMITED, CALGARY

Based on the design and cost study (Application of the LNS Burner to an Oil Field Generator) described last year, a three-year project was initiated to demonstrate the LNS Burner at an Esso Resources Canada Limited heavy oil operation near Cold Lake.

The principal objectives of the project are to demonstrate:

- the ability to burn coal in an existing heavy oil recovery (HOR) steam generator using the LNS Burner. A stand-alone, 52.7 GJ/h steam generator has been built for this purpose;
- the capability of the LNS Burner to control SO_2 and NO_x emissions at satisfactory levels while firing Alberta subbituminous coals at a commercial scale under regular operating conditions; and
- the reliability and durability of conventional, auxiliary systems operating with the burner and steam generator.

LNS Burner/Steam Generator Assembly



Thus far, the necessary equipment has been designed, constructed and installed to retrofit a LNS Burner to a coal-fired steam generator. The system is designed to provide 80 per cent quality steam at 15.5 MPa from formation waters produced along with bitumen as part of Esso's commercial project near Cold Lake. The system is designed to use Highvale coal, which averages 0.21 per cent sulphur, and to produce emissions containing less than 129 ng/J (0.3 lb./million BTU) of sulphur dioxide. This is one-half the requirement in the current Clean Air Act guideline. Also, nitrogen oxide emissions are expected to be lower than 86 ng/J (0.2 lb./million BTU), and particulate emissions should be lower than 43 ng/J (0.1 lb./million BTU). These are well below current regulations.

System startup is planned for September 1990.

Coal-Condensate Slurry Pipelining[1]

UNOCAL CANADA LIMITED, CALGARY

At the same time that steam production by coal combustion is being demonstrated as a viable technology for the extraction of heavy oil, it is also necessary to reduce the costs of transporting coal from Alberta mines to heavy oil extraction sites.

One potential method of coal transportation involves the coal-oil slurry pipelining technology being developed by Unocal Canada Limited to deliver coal to Ontario and the west coast. Some of these developments were described last year, and further information is provided in the Western Canadian Low-Sulphur Coal to Ontario section of this report.

A new project initiated this year takes advantage of the need by heavy oil producers for a hydrocarbon diluent called "condensate." This liquid is pipelined to heavy oil production areas. Thus, it was decided that the coal-oil transportation technology might be adapted to make use of the condensate and the existing condensate pipelines to transport coal to the heavy oil producing areas. Involved is the development of technology required to prepare coal-condensate slurry, pipeline it to a heavy oil field and separate it into its respective components.

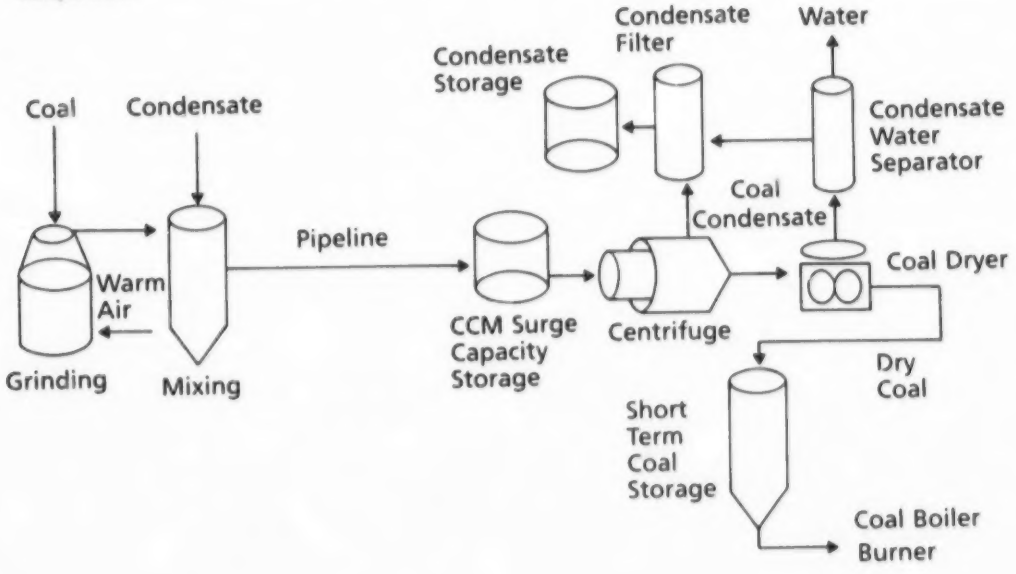
From previous work on the Unocal slurry pipeline concept, it is known that certain cost advantages relative to rail haul are likely.

For example:

- central coal grinding facilities can be located at the mine site;
- the potential combination of a slurry pipeline and the TransAlta LNS Burner could reduce the need for excess drying equipment; and
- coal from various sources could be used because the costs associated with the haul distance from a

[1]Some financial contributions were received from the Department of Western Economic Diversification.

Coal-Condensate Mixture Technology for Pipeline Slurry Transportation



mine to the user become less important when pipelines are used. Furthermore, the required pipelines already exist.

Thus far, it appears that transportation by slurry pipeline will cost less than by rail. When this cost reduction is combined with a potential rise in the cost of natural gas, the opportunities for using coal in place of natural gas are improved. To enhance this advantage, technology development is required in four key areas. They are: slurry preparation, pipelining, separation of the coal-condensate slurry, and retrofitting of gas boilers.

This year, a trial batch of Obed Mountain coal was ground to utility specifications and mixed with natural gas condensate in a specially built mixing facility at the Alberta Research Council. Slurry formulations were varied until an optimum slurry for transportation and separation was obtained. The physical and handling properties of the slurry were evaluated, and a standard industrial screen bowl centrifuge was used to separate the coal from the condensate. The centrifuged coal was heated in an industrial dryer to recover the residual condensate, which was less than 0.5 per cent. Residual particulates in the condensate were found to vary from 0.05 to 0.1 per cent.

Two 1.5-tonne samples of coal-condensate slurry were then prepared and transported to the Saskatchewan Research Council Pipeloop Testing facility in Saskatoon, where closed-loop circulation testing was carried out.

An economic evaluation of slurry pipeline transportation was performed, based on technical information derived from project activities and from the consortium that is examining the economics of coal use for heavy oil recovery.

The final stage of the project is a process engineering and cost study. It is being performed by an engineering firm that has extensive experience in slurry transportation.

Sorbent Injection Technical Committee

Although the sulphur content of some Alberta subbituminous coals is sufficiently low that current, new-source emission regulations can be met when coals are burned without sulphur oxide emission control, it was recognized that this does not apply to all Alberta subbituminous coals. Therefore, some degree of flue gas clean-up or control will be required to satisfy existing regulations and meet even more stringent guidelines that might be introduced later for emissions of SO_x and NO_x.

During 1987/88, a study of several in-furnace and post-combustion emission-control technologies was undertaken.

It was concluded that the most cost-effective approach to emission control would be to use in-furnace technology as much as possible, and supplement it with post-combustion control if emission standards become even more stringent in the future.

For the present, it was recommended that a combination of furnace sorbent injection and multi-stage burners be used. Several add-on technologies were suggested in the event of more stringent standards being imposed.

Subsequently, in October 1987 the Sorbent Injection Technical Committee[1] was established to pursue investigations involving the injection of alkali metal sorbents into coal-fired furnaces to capture acid-forming gases in the form of easily extracted particulates. The committee's principal objective is to establish whether sorbent injection is viable for sulphur gas emission control in Alberta.

Last year, some members of this group funded an investigation called Sorbent Injection Study. It was found that sulphur capture from coals having sulphur contents of approximately 0.5 per cent should range from 14 to 49 per cent. It was also determined that sorbent injection has some potential for low-cost SO_2 reduction when used at existing power plants.

The committee is considering additional projects, and has established the following subjects as having a high priority:

- State-of-the-art definition
  - influence of ash minerals on sulphur capture
  - kinetics of the sulphation reaction
  - furnace velocity/temperature profiles
  - evaluation of available technology;
- Pilot-scale experimentation
  - electrical utility pilot study
  - heavy oil recovery pilot; and
- Commercial-scale demonstration
- electrical utility demonstration
- heavy oil recovery demonstration.

[1]Current committee members are: Esso Resources Canada Limited, Edmonton Power, TransAlta Utilities Corporation, Fording Coal Limited, Alberta Power Limited, Ontario Hydro, Saskatchewan Power Corporation, Saskatchewan Energy and Mines, CANMET, and the Alberta Office of Coal Research and Technology.

Other Projects

Two studies were undertaken this year in which some fundamental properties of coal were investigated. In total, eight projects have been carried out since 1984 that were in support of other projects or program areas, or represented new areas of interest. Those active in 1989/90 are described in the following section.

Magnetic and Electric Properties of Alberta Coals

UNIVERSITY OF CALGARY
(H.A. BUCKMASTER), CALGARY

In this project, sophisticated analytical procedures were used to investigate bituminous and subbituminous Alberta coals on a molecular scale. Information about the electronic structure of atoms and molecules, and the bonds formed between various components of coal, was obtained by Continuous Wave Electron Paramagnetic Resonance (CW-EPR). The objective was to determine the role that coal rank, mineral content, maceral content and water content play in establishing the susceptibility of coals to spontaneous combustion.

This investigation was also expected to provide useful insights about free radical reactions that occur when coal is converted to liquid hydrocarbons.

A unique sample holder was designed and constructed for this study. It allowed dynamic, in situ CW-EPR studies of coals to be performed for the first time over the temperature range of 20°C to 600°C. Also developed for this project were a precise temperature controller, software that enabled the 9 GHz spectrometer to be operated under computer control, and an on-line display of information derived from the CW-EPR spectrum.

Examination of coal samples exposed to dry or moist air or nitrogen, while the temperature was varied and controlled, showed that oxidation and the removal of weakly associated water occurred differently in the bituminous and subbituminous coals. The spin concentration measured by CW-EPR increased by a factor of six in the subbituminous coal, while it increased by only a factor of two in the bituminous coal. This behaviour was noted over the temperature range 20°C to 100°C. These results confirmed that subbituminous coals are more susceptible to spontaneous combustion than bituminous coals, and the presence of oxygen is necessary for the formation of free radicals.

Similarly, an investigation of the presence of cobalt and manganese in coal showed that they play an important role in making coal more susceptible to spontaneous combustion. Also, the moisture content of a high-volatile bituminous coal affected the formation of free radicals, and the vitrinite maceral also encouraged free radical formation.

One especially interesting observation was the discovery that two free radical species were present in all coal samples. Apparently, changes in the concentration of one of these species are responsible for the observed increases in spin concentration. This is related to a coal's susceptibility to undergo spontaneous combustion.

Publications

Buckmaster, H.A. 1989. Magnetic and Electric Properties of Alberta Coals. Final Report. University of Calgary.

Buckmaster, H.A., J. Kudynska and F.W. Bachelor. 1990. Magnetic Properties of Alberta Coals. Proceedings 1990 Fundamental Coal Science Workshop and Panel Discussion, Calgary, Alberta.

Distribution of Oxygen Forms in Western Canadian Low-Rank Coals

UNIVERSITY OF ALBERTA
(N. BERKOWITZ), EDMONTON

It is generally conceded by coal scientists that the chemical properties and physical behaviour of low-rank coals are largely determined by the reactive oxygen content, which can account for 75 to 90 per cent of the total oxygen content. Also, this reactive oxygen is found in phenolic hydroxyl (-OH), carboxyl (-COOH), carbonyl (=CO) and ether (-O) groups, while unreactive oxygen exists mostly in heterocyclic combinations.

However, there is considerable uncertainty about the relative abundance of individual reactive oxygen groups in low-rank coals. Therefore, the objective of this project was to measure the concentrations and thermal stabilities of the dominant oxygen forms in a suite of Alberta bituminous and subbituminous coals. It was anticipated that this investigation might reveal an explanation for the dissimilar behaviour of coals that appear outwardly to be similar. For example, it is known that coals with virtually identical elemental and petrographic compositions will sometimes display very different pyrolytic behaviour and respond very differently to hydrogenation and solubilization in liquefaction schemes.

This year, "wet chemistry" methods were used to measure the concentration of reactive oxygen groups. The results were expressed as concentration of oxygen in each group, as weight percentages of daf coal, and as fractions of the total oxygen content of the coal.

Qualitatively, Alberta coals exhibited characteristics similar to those of other coals, but some differences did emerge. For example, they appear to contain significantly higher levels of phenolic -OH. This might explain their low tar yields when pyrolyzed. Also, from plots of oxygen species as a fraction of total oxygen, it is evident that coals appearing otherwise to be similar have a significantly different chemistry.

It was also shown that a substantial portion of the total oxygen content of low-rank coals can be removed by low-temperature pyrolytic pre-treatment. This may lead to less hydrogen use in coal liquefaction processes.

Publications

Berkowitz, N. 1990. Distribution of Oxygen Forms in Alberta Low-Rank Coals. Final Report to Alberta Office of Coal Research and Technology.

Berkowitz, N. and J. Calderon. 1990. Fuel Process Tech. 25:33.

Berkowitz, N., J. Calderon and A. Liron. 1988. Fuel. 67: 626, 1017, 1139.

Berkowitz, N. and J. Calderon. 1987. Fuel Process Tech. 16: 245.

Department-Funded Project

Alberta Coal Geology Project

ALBERTA RESEARCH COUNCIL, EDMONTON

The Alberta Coal Geology Project is funded jointly by the Alberta Office of Coal Research and Technology and the Alberta Research Council (ARC). Its overall objective is to improve the Alberta coal information base in areas where it is deficient so that industry and government can focus better on future coal development plans.

From 1974 to 1986, a coal exploration program carried out by the Alberta Research Council made a general assessment of coal reserves in Alberta's plains region, including the development of methods to predict the distribution, thickness and continuity of coal seams. The current project was begun in 1986/87, and placed greater emphasis on coal quality in the plains, foothills and mountain regions. Initially, the project comprised four subprojects. Currently, there are six, and they are described below:

Regional Coal Mapping

No consistent set of coal resource inventory maps exists for Alberta. Much of the mapping was done at the turn of the century by the Geological Survey of Canada, using a variety of scales and inconsistent nomenclature, with incomplete geographic coverage.

To bring this information up-to-date, coal resource maps at a scale of 1:50 000 are being prepared, using a standard notation and the National Topographic System (NTS) as a base. Much has been learned this century about the structure and stratigraphy of Alberta's coal-bearing region. Thus, data were obtained from the Geological Survey of Canada, individual coal mines and the Alberta Energy Resources Conservation Board. Where information was inadequate or absent, a limited amount of field investigation was undertaken.

The first year of the project focused on the Hinton-Grande Cache corridor, located in west-central Alberta. It included four contiguous NTS map sheets. From southeast to northwest, these sheets are 83F/5, 83E/9, 83E/15 and 83E/14. For each map sheet, a coal resource map and thematic "snapshot" maps at a scale of 1:250 000, with accompanying text, have been generated.

Samples collected for coal quality determination have shown that coal rank decreases towards the southwest for the base of the Gates Formation coals. Also, maturation and coalification resulted largely from sedimentary burial, although tectonic burial also played a role. The amount of tectonic burial increases from northwest to southeast. As well, the Lower Cretaceous strata in the northern and central Alberta Foothills show examples of fold-thrust interaction.

Geology of the Coalspur Coalfield

It is thought that the next thermal coal-mine to be opened in Alberta may be located in the Coalspur coalfield southwest of Edson, but the area has not been mapped since 1929. Thus, there is an urgent need to update the stratigraphic, structural and coal-quality information for this area.

This year, the Cadomin East (NTS 83F/3 East) map sheet was completed. It shows the stratigraphic and structural framework of the coal-bearing and surrounding strata, clearly displaying the three parallel bands of coals of economic interest in the Entrance Syncline and Coalspur Triangle Zone (formerly called Coalspur Anticline). The Mercoal band is the southernmost. It contains the Mercoal Project of Manalta Coal Limited and dips approximately 30 degrees to the northeast. The southwest dipping Coalspur band is in the middle and contains the structurally thickened Coal Valley pod. It is truncated by the Pedley Thrust, which is a northeast dipping reverse fault forming the northeast side of the

Coalspur Triangle Zone. The Robb band is the most northerly. It contains northeast dipping strata and is less deformed than the Coalspur band. The Bryan Mountain open pit, situated on property held by Crowsnest Resources Ltd., is located in this band.

Coal Quality Data Acquisition
Last year, a study was made of the Ardley coal zone. Work continued on the development of a coal quality predictive model that should be useful for interpreting and evaluating coals formed in similar sedimentary (depositional) environments. Ardley coals were formed largely in broad terrestrial fresh water swamps that lay between large, widely spaced drainage courses. In addition to these modelling studies, co-operative data acquisition programs with industry were prepared.

Data evaluation was concentrated primarily on a relatively small, but intensively sampled, area of the Highvale mine, 70 km west of Edmonton. In addition to the mathematical models created, bar graphs, line graphs and tables were prepared to allow rapid visual comparisons. In carrying out these evaluations, comparisons were made of the variations in air-dried ash, sulphur content and heating value of coals within individual seams of each drill hole in the area. An Alberta Research Council open-file report detailing this evaluation is expected to be available in the summer of 1990.

Coal Data Base
In support of the other projects in the program, a data base was designed and is being maintained in a form useful to planners, resource managers and geoscientists.

This year, initial storage of information in the coal data base was completed, and the data base was made available to prospective users. Requests for information were received from industry and ARC geoscientists. Thus, the design, development and testing phases of this subproject were completed this year.

Coal Geology – Outreach
The primary purpose of this subproject is to foster an increased public awareness of coal geoscience through presentations by staff of Alberta Geological Survey to community and service groups, as well as technical organizations such as The Coal Association of Canada. Also, staff exchanges with government and industry will be arranged.

This year, a visiting Chinese scientist was hosted, five papers and two articles were written, and AGS personnel served on several boards and committees.

Coal Geological Information System
In this subproject, the type of geological information about coal that is normally found on maps is being stored electronically for retrieval by geologists and resource planners. The system handles geographically or spatially referenced point data, and was used to begin building a series of spatially related base maps.

A digital version of the provincial base map was prepared, using data from the Department of Forestry, Lands and Wildlife. The geology of the undeformed region of Alberta south of Lesser Slave Lake was digitized, and a digital map of coalfields defined by the Energy Resources Conservation Board was prepared. All the coal locations stored in the data base were converted into a digital, topographical map. Currently, the most basic locational information from the coal data base is available in the system.

The project was completed.

Publications

Kalkreuth, W., C.W. Langenberg and M. McMechan. 1989. Regional Coalification Pattern of Lower Cretaceous Coal-Bearing Strata, Rocky Mountain Foothills and Foreland, Canada - Implications for Future Exploration. International Journal of Coal Geology, 13:261-302.

Langenberg, C.W. and D. Fietz. 1990. Geology of the Cadomin East (83F/3 East) Map Sheet. Alberta Research Council Open-File Report 1990-12.

Langenberg, C.W., D.E. Macdonald and W. Kalkreuth. 1990. Coal Quality Variation in the Cadomin-Luscar Coalfield, Alberta. In Proceedings of the 1990 Fundamental Coal Science Workshop and Panel Discussion, 207-241.

Langenberg, C.W., D.E. Macdonald, W. Kalkreuth and R. Strobl. 1989. Coal Quality Variation in the Cadomin-Luscar Coalfield. Alberta Research Council, Earth Sciences Report 89-1.

Langenberg, C.W., W. Kalkreuth and R. Dawson. 1989. Influences of Structural Setting on Coal Rank and Thickness in the Grande Cache Area, Alberta, Canada. Geologie en Mijnbouw, 68:241-252.

Langenberg, C.W. and W. Kalkreuth. (In press). Tectonic Controls on Regional Coalification and Vitrinite Anisotrophy of Lower Cretaceous Coals in the Alberta Foothills, Alberta. Bulletin de BRGM.

Langenberg, C.W., D.E. Macdonald, W.D. Kalkreuth, R.S. Strobl and B. Bahnsen. 1988. An Initial Assessment of Controls on Coal Quality Variation in the Cadomin-Luscar Coalfield. Alberta Research Council Open File Report 1988-06.

Langenberg, C.W., W.D. Kalkreuth and C.B. Wrightson. 1987. Deformed Lower Cretaceous Coal-Bearing Strata of the Grande Cache Area, Alberta. Alberta Research Council Bulletin No. 56.

Langenberg, C.W., D.E. Macdonald and R.J.H. Richardson. 1986. Geological Studies of Coal in Alberta: Status Report. Alberta Research Council Open File Report 1986-14.

Macdonald, D.E., C.W. Langenberg and T. Gentzis. 1989. A Regional Evaluation of Coal Quality in the Foothills/Mountains Region of Alberta. Alberta Research Council, Earth Sciences Report 89-2.

Macdonald, D.E., C.W. Langenberg and R.S. Strobl. 1988. Cyclic Sedimentation in the Lower Cretaceous Luscar Group and Spirit River Formation of the Alberta Foothills and Deep Basin. Canadian Society of Petroleum Geologists.

Macdonald, D.E., C.W. Langenberg and R.S. Strobl. 1988. The Importance and Recent Advances in Geological Coal Quality Studies in Alberta. Prepared for Canadian Institute of Mining and Metallurgy Annual General Meeting, Edmonton.

Macdonald, D.E., N. Chidambaram, C.W. Langenberg, G.B. Mandryk, C.E. Sterenberg and A. Cameron. 1987. A Regional Evaluation of Coal Quality in the Southern and Central Foothills/Mountains Region of Alberta. Alberta Research Council Open File Report 1987-9.

Mandryk, G., R.J.H. Richardson and D. Fietz. 1989. The Alberta Geological Survey Coal Data Base. Abstract CSPG Exploration Update '89.

Mandryk, G., R.J.H. Richardson and D. Fietz. 1989. The Alberta Geological Survey Coal Data Base. Western Canada Coal Geoscience Forum, Edmonton, Alberta. Conference Proceedings.

Mandryk, G.B. and R.J.H. Richardson. 1988. Coal Resource Data in the Plains Area of Alberta. Alberta Research Council Open File Report 1988-07.

Nikols, D., S. Treasure and R. Strobl. 1990. Coal Quality Variation. In Proceedings of 1990 Fundamental Coal Science Workshop and Panel Discussion, 178-206.

Richardson, R.J.H., C.W. Langenberg, D.K. Chao and D. Fietz. 1990. Coal Compilation Project - Entrance NTS 83F/5. Alberta Research Council Open-File Report 1990-2.

Richardson, R.J.H., C.W. Langenberg, D.K. Chao and D. Fietz. 1990. Coal Compilation Project - Moberly Creek NTS 83E/9. Alberta Research Council Open-File Report 1990-3.

Richardson, R.J.H., C.W. Langenberg, D.K. Chao and D. Fietz. 1990. Coal Compilation Project - Pierre Greys Lakes NTS 83E/15. Alberta Research Council Open-File Report 1990-4.

Richardson, R.J.H., C.W. Langenberg, D.K. Chao and D. Fietz. 1990. Coal Compilation Project - Grande Cache NTS 83E/14. Alberta Research Council Open-File Report 1990-5.

Richardson, R.J.H., C.W. Langenberg, D.K. Chao and D. Fietz. 1990. Regional Coal Mapping - Moberly Creek NTS 83E/9. Alberta Research Council RCM1.

Richardson, R.J.H., C.W. Langenberg, D.K. Chao and D. Fietz. 1990. Regional Coal Mapping - Pierre Greys Lakes NTS 83E/15. Alberta Research Council RCM2.

Richardson, R.J.H., C.W. Langenberg, D.K. Chao and D. Fietz. 1990. Regional Coal Mapping - Grande Cache NTS 83E/14. Alberta Research Council RCM3.

Richardson, R.J.H., C.W. Langenberg, D.K. Chao and D. Fietz. 1990. Regional Coal Mapping - Entrance NTS 83F/5. Alberta Research Council RCM4.

Richardson, R.J.H., D.K. Chao and R.M. Krzanowski. 1989. Coal Geology Geoscience Information System Pilot Study. Alberta Research Council Open-File Report 1989-03A and B.

Richardson, R.J.H., G. Mandryk and D. Fietz. 1989. Coal Geology Data Base. Alberta Research Council Open-File Report 1989-02A, B, C and D.

Richardson, R.J.H., D.K. Chao and R.M. Krzanowski. 1989. A Geoscience Information System (GSIS) for Alberta Coal. Western Canada Coal Geoscience Forum, Edmonton, Alberta. Conference Proceedings.

Richardson, R.J.H., R.S. Strobl, D.E. Macdonald, J.R. Nurkowski, P.J. McCabe and A. Bosman. 1988. An Evaluation of the Coal Resources of the Ardley Coal Zone to a Depth of 400 m in the Alberta Plains Area. Alberta Research Council.

Wong, R., R.S. Strobl, R. Krzanowski and N. Chidambaram. 1988. Exploratory Statistical Analysis of Coal Quality at the Highvale Mine (Ardley Coal Zone), Central Alberta. Alberta Research Council.

Western Canadian Low-Sulphur Coal to Ontario Program

Since the mid-1980s, the potential social and economic benefits of using increased amounts of western Canadian coal in Ontario have been investigated and described by various federal/provincial task forces representing the federal government and the governments of Ontario and the western coal-producing provinces. The most recent of these groups, called the Action Committee on Western Canadian Low-Sulphur Coal to Ontario, comprises the Deputy Prime Minister and the premiers of British Columbia, Alberta, Saskatchewan and Ontario. In 1987, this committee created an Intergovernmental Secretariat which consulted with coal producers, transporters and users to develop possible technological, regulatory and policy options that could lower the delivered cost of western Canadian coal in Ontario.

In its November 1987 report to the Action Committee, the Secretariat identified 14 research and development initiatives within four broad categories that should be pursued. They are as follows:

- Mine Production Improvements;
- Coal Product Improvements;
- Transportation Improvements; and
- Fiscal and Regulatory Improvements.

While each of these initiatives will involve co-operation among the member governments and industry, the Alberta government has agreed to take the lead in implementing the following three initiatives:

- Underground Thick Seam Extraction Using the Room and Pillar System of Mining;
- Ash Reduction, Refuse Reprocessing and Fines Processing; and
- Coal-Oil Mixture Slurry Transportation Concept.

Some of these activities and those led by other governments or The Coal Association of Canada are directed by technical committees comprising representatives of interested governments and industries.

The program includes studies of the impact of taxes and regulatory costs on coal transportation by railways and pipelines, and on coal producers.

Thick Seam Extraction and Continuous Haulage Mining Demonstration

SMOKY RIVER COAL LIMITED, GRANDE CACHE

Considerable reserves of high-quality thermal and metallurgical coal are present in seams more than 3.7 m thick in western Canadian coal mines, but many of these seams are steeply inclined and difficult to mine using current extraction methods. These methods are generally limited to seams that are 3 m thick, leaving large quantities of coal unmined.

However, recent developments in machinery design and mining systems suggest that seams up to 6 m thick can be mined successfully. This permits higher rates of resource recovery and improvements in productivity and costs.

Consequently, this multi-year project is evaluating new methods of safely removing coal using flexible conveyor train (FCT) technology, 6-m high pillars and ribs, and mobile roof support systems in the underground mine.

This year, an innovative roof and side bolter was designed, fabricated and used successfully to support the roof and sides. The presence of sheared coal, however, prevented using the full height capabilities of the equipment. Thus far, heights of only 3.7 to 4.3 m could be excavated safely.

Also, problems with the electrical and mechanical systems of the FCT prevented it from becoming fully operational. Changes are being made to both the FCT equipment and associated software.

The project is continuing.

The project is being financed equally by Smoky River Coal Limited, the Department of Western Economic Diversification and the Alberta Office of Coal Research and Technology.

Publications

Kulach, J. and H.H. Sandkuhler. 1990. Continuous Transport of Materials, Underground Flexible Conveyor System. CIM 92nd Annual General Meeting, Ottawa, Ontario.

Kulach, J. 1989. Thick Seam Underground Mining Demonstration Project. Ground Control Monitoring and Instrumentation Plan. Smoky River Coal Limited.

Kulach, J. and H.H. Sandkuhler. 1989. Thick Seam Underground Mining Demonstration Project. CIM Conference, Calgary, Alberta.

Associated Mining Consultants Limited. 1989. Geotechnical Monitoring Thick Seam Room-and-Pillar Demonstration Project. A report to Smoky River Coal Limited.

Fine Coal Cleaning Technical Committee

In recognition of the problems caused by coal fines, a Fine Coal Cleaning Technical Committee[1] was established in 1988 to provide a method for co-ordinating and funding research efforts. This was given impetus by the report of the Intergovernmental Secretariat to the Action Committee on Western Canadian Low Sulphur Coal to Ontario, which recommended that Alberta should take the lead role in initiating research on fine coal cleaning.

The objectives of the committee are:

- to find ways to reduce the delivered cost of coal in Ontario by improving fine coal cleaning while maintaining coal quality at its current level;
- to achieve fine coal recovery so as to satisfy concerns about environmental and resource exploitation efficiency while reducing tailings disposal costs; and
- to develop fine coal products that are acceptable to existing or potential markets.

Topics to be considered for research efforts include:

- Fines Processing
  - Utilization
  - Coal Surface Properties
  - Flotation Techniques
  - Yield Improvement
- Ash Reduction
  - Separation by Size/Specific Gravity
  - Chemical Change/Oxidation/Storage
  - Process Automation
  - Ash Surface Properties
- Refuse Reprocessing
  - Tailings and Reclamation
  - Slack Pile Reclamation
  - Environmental Considerations

Projects supported thus far by members of the Fine Coal Cleaning Technical Committee include: Electrocoagulation, Air-Sparged Hydrocyclone, HYDROSIZER for Fine Coal Recovery from Tailings, and Tailings Reclamation.

[1]Committee members on March 31, 1990 were: Obed Mountain Coal Company Limited, Gulf Canada Resources Limited, Fording Coal Limited, Luscar Sterco (1977) Ltd., Luscar Ltd., Esso Resources Canada Limited, Smoky River Coal Limited, Gregg River Resources, Quintette Coal Limited, Cardinal River Coal, ARC/Cyclone Engineering Sales, The Coal Association of Canada, CANMET, British Columbia Mines, Energy and Petroleum Resources, Saskatchewan Energy and Mines, Ontario Hydro, Department of Western Economic Diversification, and Alberta Office of Coal Research and Technology, assisted by the Coal Mining Research Company.

Air-Sparged Hydrocyclone

HYDRO PROCESSING & MINING LTD., CALGARY

As world coal markets become more competitive, the ability to clean the fine components of western coals becomes more important. One fine coal cleaning method that is showing promise relative to conventional flotation methods, uses a patented device called an Air-Sparged Hydrocyclone. It was developed at the University of Utah.

During 1989/90, a 15-cm Air-Sparged Hydrocyclone was installed at the Fording River coal mine, but some difficulty was encountered in operating it consistently. It appears that as many as seven operating variables affect the efficiency of the device. Nonetheless, a similar unit was installed at the Smoky River coal mine. It will be tested next year.

Financing is being provided by Hydro Processing & Mining Ltd., the Department of Western Economic Diversification and the Alberta Office of Coal Research and Technology.

Earlier work on automedium cyclones was described in this technology transfer booklet.

HYDROSIZER for Fine Coal Recovery from Tailings

OBED MOUNTAIN COAL COMPANY LIMITED, CALGARY

Coal-cleaning experience elsewhere has shown that the patented HYDROSIZER device effectively separates low-density, undesirable material from fine coal (0.55 x 0.1 mm) having specific gravity values of less than 1.5.

In this project, the device was tested for the first time on western Canadian coals. A pilot unit at the Obed Mountain mine was fed with a 1.2 x 0 mm raw coal slurry partially deslimed at 0.15 mm. Two full performance tests were undertaken over a range of cut points.

The performance was separately evaluated for the following 2:1 size fractions: 1.2 x 0.6 mm, 0.6 x 0.3 mm, 0.3 x 0.15 mm. Mass and ash balances, and float-sink analyses provided data for determining partition curves for each fraction.

Low cut points were achieved for material coarser than 0.6 mm, although the separations were not as sharp as those reported in the literature. Some suggestions were made to improve this performance. Products coarser than 0.3 mm met clean coal specifications for ash content. This result cannot be achieved by other devices using single-stage cleaning of this particular clay-contaminated thermal coal.

The project was completed. It was financed by Obed Mountain Coal Company Limited and the Alberta Office of Coal Research and Technology.

Publication

Butcher, S.G. and A.L. Craven. 1989. HYDROSIZER for Fine Coal Recovery from Tailings. Coal Mining Research Company.

Testing of ARCOFLUX 130

OBED MOUNTAIN COAL COMPANY LIMITED, CALGARY

ARCOFLUX 130 was examined as a potential deactivant to prevent thermally dried low-rank coals from combusting spontaneously.

In a study carried out by the Coal Mining Research Company, coals from the Obed Mountain, Highvale and Costello mines were dried to less than their equilibrium moisture content. These values were 8, 8 and 17 per cent, respectively. After cooling, the dried coals were treated by spraying with ARCOFLUX 130.

The stability of the treated coals, with respect to spontaneous combustion and moisture sorption potential, was determined and compared with the same coals in a moist or dry, untreated state.

It was found that the dried coals, whether treated with ARCOFLUX 130 or not, were significantly more reactive than the comparable moist feed. Also, it was noted that the coals treated with ARCOFLUX 130 did not exhibit significantly improved stability or moisture sorption properties relative to the untreated dried coals.

The project was completed. It was financed by Obed Mountain Coal Company Limited, Department of Western Economic Diversification, Saskatchewan Energy and Mines, Ontario Ministry of Energy, and the Alberta Office of Coal Research and Technology.

Publication

Germain, R.J. 1989. An Evaluation of ARCOFLUX 130 Applied to Western Canadian Low Rank Coals. Coal Mining Research Company.

On-Line Coal Analysers

RADIOMETRICS ENGINEERING LTD., CALGARY

The operation of coal preparation plants or coal combustion facilities would be enhanced if coal characteristics such as moisture, sulphur and sodium content could be determined on-line instead of requiring spot sampling and laboratory analysis.

Thus, the objective of this project is to demonstrate: (1) the capability of the RadioMetrics Magnetic Resonance on-line analyser to measure surface moisture, inherent moisture, sodium and volatiles, and; (2) the capability of the RadioMetrics X-Ray Fluorescence on-line analyser to measure sulphur and other ash elements. Each of these instruments is to be used in an operating environment.

This project was initiated late in the fiscal year. Equipment selection was under way by year end.

Financial support for this project is being provided by Alberta Power Limited, RadioMetrics Engineering Ltd., Canadian Electrical Association, Department of Western Economic Diversification, and the Alberta Office of Coal Research and Technology.

Tailings Reclamation

LUSCAR STERCO (1977) LTD., (EDSON) AND OBED MOUNTAIN COAL COMPANY LIMITED, (HINTON)

All coal preparation plants generate coal refuse known as tailings. Depending on the type of coal being mined, as well as the preparation plant yield and the amount of clay present in the tailings, the disposal of tailings into holding ponds can represent a significant portion of preparation plant operating costs.

Various methods for de-watering slurries containing tailings have been tried, including mechanical de-watering using filter presses. In this project, however, an alternative method is being tried. It involves dewatering an existing tailings pond and experimenting with various methods for stabilizing and reclaiming it. The intention is to determine how much topsoil and sub-soil are needed to reclaim the tailings pond in an environmentally sustainable manner.

This year, a 3-ac. parcel of the drained holding pond was prepared with various thicknesses of topsoil. In one case, some spoil was also used. These plots were seeded with reed canary grass, alfalfa, timothy, clover and redtop.

This work was preceded by greenhouse tests to identify plant species capable of growth on the tailings pond. These tests were carried out on tailings alone, soil alone, soil over tailings, and a mixture of soil and tailings.

Meanwhile, geotechnical assessment of the site began. This included installation of piezometers and settlement plates, as well as performing vane shear and cone penetrometer tests.

Financial support for this project is being provided by Luscar Sterco (1977) Ltd., Obed Mountain Coal Company Limited, Department of Western Economic Diversification and the Alberta Office of Coal Research and Technology.

transCOM Co-ordinated Vendor Tests

UNOCAL CANADA LIMITED, CALGARY

An earlier study estimated that the cost of transporting Alberta coal to Ontario can be reduced if slurries of coal and oil are pumped in batch mode through existing oil pipelines, rather than being shipped in bulk by rail or truck as is done now.

In that earlier project for the Office, a laboratory-scale technical study was performed to assess the merits of the coal slurry pipeline option for delivering coal to Ontario. Using the results of laboratory testing and pipeloop studies at the Saskatchewan Research Council, a preliminary economic study found that such a system could be viable when the demand for coal at a single power plant in Ontario was 1 - 2 million tonnes per year.

In an extension of the earlier project, the objective of the current project is to scale up the entire chain of preparation, transportation and separation stages.

Last year, basic work was undertaken to determine the optimum process for preparing these unique slurries. This included studying dry versus wet grinding of coal, and use of ash removal-oil agglomeration, which was carried out at the National Research Council. Techniques were successfully developed to produce consistently stable slurries and identify quality control tests.

In total, over 50 tonnes of coal were dry-ground to a utility particle size and shipped to the Alberta Research Council facilities at Nisku. Slurries were mixed using the proprietary preparation process, and several pipeline tests were conducted. One test involved trucking a slurry to the site of a 76-mm pipeline owned by Unocal, and injecting batches of the slurry into an on-line system. The slurry/oil interface growth was monitored over a 30-km distance and found to be acceptable. Another series of pipeloop tests was conducted at the Saskatchewan Research Council to determine the laminar flow and laminar/turbulent transition characteristics of the slurry.

Slurry from the 30-km field test was then returned to Nisku for a series of separation tests. Using commercially available equipment, the slurry was routinely separated in a 3-ton-an-hour screen bowl centrifuge. The recovered coal cake was then dried in an indirectly heated screw-type dryer. The resulting coal product, containing approximately five per cent oil, was shipped to Ontario Hydro for combustion testing. The oil product, containing 1 000 to 2 000 ppm solids, was sent to a refinery-oil cleaning specialist in Houston for removal of the solids by conventional de-salting. Early results from both of these product tests appear positive.

The final step of this research, currently under way, involves contracting with a major engineering consultant to prepare process flow sheets and cost estimates for a two-million-tonne-a-year slurry preparation and separation plant.

Financial support is being provided by Unocal Canada Limited, Department of Western Economic Diversification, Ontario Ministry of Energy and the Alberta Office of Coal Research and Technology.

Project Expenditures

Table I: Funding Contributions to Approved Projects by Year ($)

Project Title	1977/78	1978/79	1979/80	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86	1986/87	1987/88	1988/89	1989/90	Projected Future Funding	Total
A/CERRF-Funded Projects															
Resource Evaluation															
Analysis of Coal-Bearing Strata Near Cadomin	-	507	15,762	3,731	-	-	-	-	-	-	-	-	-	-	20,000
Creep Characteristics of Coal	-	-	-	-	-	-	14,439	2,020	-	-	-	-	-	-	16,459
Reflective Seismic Investigation of Western Canadian Coalfields	-	-	-	-	35,668	17,760	3,564	-	-	-	-	-	-	-	56,992
VLF Geophysical Methods in Coal Exploration	-	-	-	-	-	-	-	4,426	10,420	-	-	-	-	-	14,846
Potential of Geophysical Techniques for Coal Exploration	-	-	-	-	-	-	-	-	69,470	-	-	-	-	-	69,470
Geotechnical Properties of Overburden	-	-	-	-	-	-	-	-	71,501	-	-	-	-	-	71,501
Surface Geophysical Coal Exploration	-	-	-	-	-	-	-	96,915	112,053	124,500	-	-	-	-	333,468
Structural Geometry of Imbricated Thrust Sheets	-	-	-	-	-	-	-	-	22,873	30,127	-	-	-	-	53,000
In-Seam Coal Characterization	-	-	-	-	-	-	-	-	-	93,111	143,713	-	-	-	236,824
Seismic Modelling of Shallow Coalfields	-	-	-	-	-	-	-	-	-	24,723	7,720	37,096	159	-	69,698
Downhole Geophysics	-	-	-	-	-	-	-	-	-	30,667	44,099	104,500	-	-	179,266
Surface Geophysical Techniques for Foothills and Mountain Coalfield Exploration	-	-	-	-	-	-	-	-	-	-	-	73,835	47,094	152,500	273,429
Subtotal: Resource Evaluation	**0**	**507**	**15,762**	**3,731**	**35,668**	**17,760**	**18,003**	**103,361**	**286,317**	**303,128**	**195,532**	**215,431**	**47,253**	**152,500**	**1,394,953**
Mining															
Support Design for Underground Cavities in Weak Rock	132,154	-	-	-	-	-	-	-	-	-	-	-	-	-	132,154
Coal Mining Research	14,692	67,595	115,347	181,640	225,662	296,129	358,220	278,838	417,439	-	-	-	-	-	1,955,562
Coal Mining in 2035	-	-	-	-	-	-	-	-	78,682	-	-	-	-	-	78,682
Triaxial Test Development	-	-	-	-	-	-	-	-	-	103,503	-	-	-	-	103,503
Ground Movements in Coal Mines	-	-	-	-	-	-	-	-	11,469	14,031	-	-	-	-	25,500
Mining 2035 Workshop	-	-	-	-	-	-	-	-	-	25,226	-	-	-	-	25,226
Robotics for Mine Control	-	-	-	-	-	-	-	-	-	96,178	-	-	-	-	96,178
Non-Cable Vehicle Guidance	-	-	-	-	-	-	-	-	-	-	133,455	-	-	-	133,455
Lasers in Coal Mining	-	-	-	-	-	-	-	-	-	-	50,954	-	-	-	50,954
Geostatistics	-	-	-	-	-	-	-	-	-	-	40,958	-	-	-	40,958
Footwall Anchoring	-	-	-	-	-	-	-	-	-	81,246	57,853	-	-	-	139,099
Time-Dependent Behaviour of Coal Measure Rocks	-	-	-	-	-	-	-	-	-	15,288	19,745	4,967	-	-	40,000
Deformation and Progressive Failure of Open-Pit Highwalls	-	-	-	-	-	-	-	-	-	44	71,934	12,724	-	-	84,702
Automated Machine Control for Optimized Mining (AMCOM)	-	-	-	-	-	-	-	-	-	-	-	197,222	-	-	197,222
Dragline Operations Monitor	-	-	-	-	-	-	-	-	-	-	-	40,225	-	-	40,225
Subtotal: Mining	**146,846**	**67,595**	**115,347**	**181,640**	**225,662**	**296,129**	**358,220**	**278,838**	**507,590**	**335,516**	**374,899**	**255,138**	**0**	**0**	**3,143,420**

Project Title	1977/78	1978/79	1979/80	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86	1986/87	1987/88	1988/89	1989/90	Projected Future Funding	Total
Preparation and Upgrading															
Coal Ash Monitoring System	-	13 555	24 185	25 130	8 763	-	-	-	-	-	-	-	-	-	71 633
Mathematical Modelling of Automedium Cyclones	-	-	-	-	22 929	34 842	37 940	-	-	-	-	-	-	-	95 711
Beneficiation of Coal by Agglomeration in Pipelines	-	-	-	49 944	60 947	74 523	22 220	-	-	-	-	-	-	-	207 634
Coal Preparation Research	39 845	183 315	312 815	492 675	612 060	803 189	835 845	1 188 731	224 014	-	-	-	-	-	4 692 489
Coal Comminution	-	-	-	-	-	-	-	-	-	54 466	-	-	-	-	54 466
Numerical Analysis of Process Yield Losses	-	-	-	-	-	-	-	-	56 000	19 795	-	-	-	-	75 795
Advanced Processes for Low-Rank Coal	-	-	-	-	-	-	-	-	-	79 392	-	-	-	-	79 392
Properties of Thermally Dried Coals	-	-	-	-	-	-	-	-	99 459	45 000	-	-	-	-	144 459
Stabilization of Dried Coal	-	-	-	-	-	-	-	-	-	37 423	-	-	-	-	37 423
Agglomeration of Low-Rank Alberta Thermal Coals	-	-	-	-	-	-	136 754	-	-	-	-	(5 969)	-	-	130 785
Agglomeration for Beneficiation	-	-	-	-	-	-	-	-	18 444	31 328	-	-	-	-	49 772
Preparation and Upgrading Assistance	-	-	-	-	-	-	-	-	-	705	41 295	-	-	-	42 000
Moisture and Ash On-Stream Analyser	-	-	-	-	-	-	-	-	-	-	26 553	-	-	-	26 553
Recovery of Coal from Tailings	-	-	-	-	-	-	-	-	-	-	82 231	-	-	-	82 231
Fine Coal Technical Assistance	-	-	-	-	-	-	-	-	-	-	2 308	-	-	-	2 308
Froth Flotation Study at Coal Valley	-	-	-	-	-	-	-	-	-	-	29 237	-	-	-	29 237
Washery Optimization	-	-	-	-	-	-	-	-	-	93 876	127 102	-	-	-	220 978
Coal Beneficiation Process	-	-	-	-	-	-	-	68 546	153 438	595 072	75 330	23 461	-	-	915 847
Agglomeration of Coking Coal	-	-	-	-	-	-	-	-	-	-	90 000	-	-	-	90 000
Westcoal Separator	-	-	-	-	-	-	-	-	-	-	-	24 898	-	-	24 898
Coal Production Program Planning	-	-	-	-	-	-	-	-	-	-	-	36 750	6 484	-	43 234
Electrocoagulation	-	-	-	-	-	-	-	-	-	-	-	15 046	-	33 333	48 379
Coal Agglomeration Process Development	-	-	-	-	-	-	-	-	-	-	35 000	35 000	17 500	38 500	126 000
Particle Distribution in Slurry Flow Through Tees and Manifolds	-	-	-	-	-	-	-	-	-	-	-	53 222	43 570	16 208	113 000
Subtotal: Preparation and Upgrading	**39 845**	**196 870**	**337 000**	**567 749**	**704 699**	**912 554**	**1 032 759**	**1 257 277**	**551 355**	**957 057**	**509 056**	**182 408**	**67 554**	**88 041**	**7 404 224**
Combustion															
Smoky DENSECOAL Combustion Tests	-	-	-	-	-	-	-	-	9 560	-	-	-	-	-	9 560
Combustion of Agglomerated Coal	-	-	-	-	-	-	-	2 061	22 950	8 325	-	-	-	-	33 336
Combustion Process Research	-	-	-	-	-	-	-	-	25 215	125 000	-	-	-	-	150 215
Combustion Characteristics of Alberta Coals	-	-	-	-	-	-	-	-	97 849	91 121	-	-	-	-	188 970
Combustibility of Agglomerates	-	-	-	-	-	-	-	-	-	14 156	-	-	-	-	14 156
Combustion Program Planning	-	-	-	-	-	-	-	-	39 612	18 991	18 000	-	-	-	76 603
Influence of Porosity on Combustion	-	-	-	-	-	-	-	-	-	-	84 000	-	-	-	84 000

Project Title	1977/78	1978/79	1979/80	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86	1986/87	1987/88	1988/89	1989/90	Projected Future Funding	Total
Causes of Spontaneous Combustion of Western Canadian Coals	-	-	-	-	-	-	-	-	-	52 040	46 396	705	-	-	99 141
Combustibility of Upgraded Alberta Coals	-	-	-	-	-	-	-	-	-	-	115 000	-	-	-	115 000
Evaluation of Blending on Combustibility	-	-	-	-	-	-	-	-	-	-	36 000	-	-	-	36 000
Prediction of Coal Combustibility	-	-	-	-	-	-	-	-	83 359	56 463	7 594	-	-	-	147 416
Combustion Properties of Alberta Coals and Chars	-	-	-	-	-	-	-	-	-	-	-	150 000	-	-	150 000
Spontaneous Combustion of Thermally Treated Coals	-	-	-	-	-	-	-	-	-	-	-	25 503	-	-	25 503
International Energy Agency Basic Coal Combustion Science	-	-	-	-	-	-	-	-	101 619	184 708	146 368	32 869	-	-	465 564
A Thermodynamic Model for Spontaneous Combustion of Coal	-	-	-	-	-	-	-	-	-	-	-	54 567	40 918	-	95 485
Sources of Ash Under Controlled Conditions	-	-	-	-	-	-	-	-	-	-	-	-	5 231	-	5 231
International Energy Agency Basic Coal Combustion Science Extension	-	-	-	-	-	-	-	-	-	-	-	-	94 640	102 383	197 023
Coal Utilization Program Planning	-	-	-	-	-	-	-	-	-	-	-	38 808	39 227	45 000	123 035
Ash Properties of Alberta Coals	-	-	-	-	-	-	-	-	-	-	-	-	49 962	150 000	199 962
Subtotal: Combustion	0	0	0	0	0	0	0	2 061	380 164	550 804	453 358	302 452	229 978	297 383	2 216 200
Liquefaction															
Coal Liquefaction Study	-	-	-	151 864	-	-	-	-	-	-	-	-	-	-	151 864
Coal Liquefaction Feasibility Study	-	-	-	-	-	-	-	90 553	-	-	-	-	-	-	90 553
Synthetic Fuels Program	-	-	-	-	-	-	-	48 220	-	-	-	-	-	-	48 220
Economic Evaluation of Coal/Oil Co-processing	-	-	-	-	-	-	-	43 943	4 174	-	-	-	-	-	48 117
PYROSOL Process Review	-	-	-	-	-	-	-	-	7 006	-	-	-	-	-	7 006
Liquefaction Process Improvement	-	-	-	-	-	-	-	-	51 059	-	-	-	-	-	51 059
Hydroprocessing of Coal-Based Liquids	-	-	-	-	-	45 593	34 463	4 880	-	-	-	-	-	-	84 936
Supercritical Gas Extraction of Coal	-	-	-	-	-	30 611	31 208	5 473	-	-	-	-	-	-	67 292
ENR/ARC Coal Conversion Research	2 055	-	37 412	1 182 372	3 135 406	4 158 527	3 034 865	2 085 164	706 548	-	-	-	-	-	14 342 349
New Liquefaction Processes	-	-	-	-	-	-	-	-	32 949	198 000	-	-	-	-	230 949
Liquefaction Process Evaluation	-	-	-	-	-	-	-	-	26 191	51 600	-	-	-	-	77 791
Isotopic Analysis of Co-processing Schemes	-	-	-	-	-	-	-	-	22 082	51 918	-	-	-	-	74 000
Secondary Upgrading	-	-	-	-	-	-	-	-	-	-	182 671	329	-	-	183 000
Functional Group Analysis of Coal Liquids	-	-	-	-	-	-	-	-	30 515	49 793	10 692	-	-	-	91 000
Chemistry of Coal Liquefaction	-	-	-	-	-	-	-	-	84 232	121 000	303 672	5 753	-	-	514 657
Secondary Upgrading of Co-processing Products	-	-	-	-	-	-	-	-	-	-	-	172 000	-	-	172 000
Supercritical Gas Extraction of Coal	-	-	-	-	-	-	-	-	-	27 588	45 617	9 071	-	-	82 276
Liquefaction of Coal with Natural Gas	-	-	-	-	-	-	-	-	-	-	29 404	6 346	-	-	35 750
Hydroprocessing of Coal-Derived Liquids	-	-	-	-	-	-	-	-	-	15 607	46 209	24 205	19 379	-	105 400

Project Title	1977/78	1978/79	1979/80	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86	1986/87	1987/88	1988/89	1989/90	Projected Future Funding	Total
Isotopic Studies of Coal/Bitumen Co-processing Schemes	-	-	-	-	-	-	-	-	-	-	77 784	43 508	(566)	-	120 726
Molecular Interactions Between Heavy Oil and Coal Species During Co-processing	-	-	-	-	-	-	-	-	-	-	-	48 464	54 813	3 123	106 400
Product and Process Characterization	-	-	-	-	-	-	-	-	-	-	-	218 156	86 864	80 000	385 020
Co-processing Process Development	-	-	-	-	-	-	-	-	-	2 282 650	603 461	630 249	643 763	260 000	4 420 123
Combined Processing of Coal Heavy Oil and Natural Gas	-	-	-	-	-	-	-	-	-	-	-	-	18 783	41 217	60 000
Specialty Chemicals from Coal-Derived Liquids	-	-	-	-	-	-	-	-	-	-	-	-	79 900	90 000	169 900
Co-processing of Coal with Molten Halide Catalysts	-	-	-	-	-	-	-	-	-	-	-	-	40 000	30 000	70 000
Subtotal: Liquefaction	**2 055**	**0**	**37 412**	**1 334 236**	**3 135 406**	**4 234 731**	**3 100 536**	**2 278 233**	**964 756**	**2 798 156**	**1 299 510**	**1 158 081**	**942 936**	**504 340**	**21 790 388**
Gasification															
Gasification of Western Canadian Coals	-	-	-	-	-	-	-	-	-	88 500	-	-	-	-	88 500
Fluidized Bed Gasification of Highvale Coal	-	-	-	-	-	-	-	-	-	-	64 201	-	-	-	64 201
Economics of Coal Gasification	-	-	-	-	-	-	-	-	-	-	10 045	-	-	-	10 045
Gasification Process Research	-	-	-	-	-	-	-	-	-	12 207	72 154	(401)	-	-	83 960
Gasification Properties of Alberta Coals	-	-	-	-	-	-	-	-	-	34 957	130 000	-	-	-	164 957
Gasification Laboratory Facilities	-	-	-	-	-	-	-	-	-	-	160 000	-	-	-	160 000
Corrosion in Gasification Systems	-	-	-	-	-	-	-	-	-	50 871	43 069	460	-	-	94 400
Gasification Characteristics of Alberta Coals	-	-	-	-	-	-	-	-	-	5 466	179 850	59	-	-	185 375
Devolatilization Properties of Alberta Coals	-	-	-	-	-	-	-	-	-	-	-	150 000	28 530	-	178 530
IGCC Utility Applications	-	-	-	-	-	-	-	-	-	-	-	-	25 000	-	25 000
Gasification Properties of Alberta Coals II	-	-	-	-	-	-	-	-	-	-	-	190 000	154 000	210 000	554 000
Subtotal: Gasification	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**142 001**	**659 319**	**340 118**	**207 530**	**210 000**	**1 558 968**
Transportation															
Coal Slurry Pipeline Research	-	-	-	-	-	-	114 903	150 333	22 717	-	-	-	-	-	287 953
Coal/Oil/Natural Gas Transportation System	-	-	-	-	-	-	-	-	-	-	25 000	-	-	-	25 000
Coal Market Access Model	-	-	-	-	-	-	-	-	-	-	69 846	4 125	-	-	73 971
Coal-Oil Slurry Pipelining	-	-	-	-	-	-	-	-	-	-	204 331	455 578	-	-	659 909
Coal Slurry Technology	-	-	-	-	-	-	-	-	-	-	25 576	22 411	173 566	136 200	357 753
Subtotal: Transportation	**0**	**0**	**0**	**0**	**0**	**0**	**114 903**	**150 333**	**22 717**	**0**	**324 753**	**482 114**	**173 566**	**136 200**	**1 404 586**
Environment															
Coal Conversion Waste-Water Treatment	-	-	-	-	-	30 000	57 890	-	-	-	-	-	-	-	87 890
Low NO_x,SO_x Burner	-	-	-	-	-	-	-	-	-	50 028	-	-	-	-	50 028
Coal Conversion Waste-Water Treatment	-	-	-	-	-	-	-	-	17 305	38 577	8 118	-	-	-	64 000
Coal for Use in Enhanced Oil Recovery: Emission Control Technology	-	-	-	-	-	-	-	-	-	-	-	14 625	-	-	14 625
Sorbent Injection Study	-	-	-	-	-	-	-	-	-	-	-	15 000	-	-	15 000
Subtotal: Environment	**0**	**0**	**0**	**0**	**0**	**30 000**	**57 890**	**0**	**17 305**	**88 605**	**8 118**	**29 625**	**0**	**0**	**231 543**

Project Title	1977/78	1978/79	1979/80	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86	1986/87	1987/88	1988/89	1989/90	Projected Future Funding	Total
Markets															
Conversion from Oil to Coal Water Fuels	-	-	-	-	-	-	-	-	26 093	9 283	-	430	-	-	35 806
Production of Activated Carbon	-	-	-	32 364	7 077	-	-	759	-	-	-	-	-	-	40 200
Activated Carbon from Coal	-	-	-	-	-	-	-	-	-	31 738	57 997	10 265	-	-	100 000
Subtotal: Markets	**0**	**0**	**0**	**32 364**	**7 077**	**0**	**0**	**759**	**26 093**	**41 021**	**57 997**	**10 695**	**0**	**0**	**176 006**
Enhanced Oil Recovery															
Fuel Options for Enhanced Oil Recovery	-	-	-	-	-	-	-	-	15 000	-	-	-	-	-	15 000
Coal Use in Enhanced Oil Recovery	-	-	-	-	-	-	-	-	-	17 995	13 777	-	-	-	31 772
Coal-Fired Steam Injection Boiler	-	-	-	-	-	-	-	-	-	-	28 619	110 205	-	-	138 824
Application of the LNS Burner to an Oil Field Steam Generator	-	-	-	-	-	-	-	-	-	-	-	22 460	-	-	22 460
Economics of Coal Use for Heavy Oil Recovery	-	-	-	-	-	-	-	-	-	-	-	-	50 000	-	50 000
Coal/Condensate Slurry Pipelining	-	-	-	-	-	-	-	-	-	-	-	-	251 603	-	251 603
LNS Burner Steam Generator Demonstration	-	-	-	-	-	-	-	-	-	-	-	292 266	1 964 000	506 600	2 762 866
Subtotal: Enhanced Oil Recovery	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**15 000**	**17 995**	**42 396**	**424 931**	**2 265 603**	**506 600**	**3 272 525**
Other															
Coal Technology Information Center	-	-	-	-	-	143 753	114 830	123 537	189 000	-	-	-	-	-	571 120
Technical Information Needs	-	-	-	-	-	-	-	16 997	-	-	-	-	-	-	16 997
Data Gathering for Research Planning	-	-	-	-	-	-	-	-	10 784	41 212	-	-	-	-	51 996
Electrolysis of Coal Slurries	-	-	-	-	-	-	-	-	26 655	65 588	20 757	-	-	-	113 000
Sulphur Isotope Studies of Coal	-	-	-	-	-	-	-	-	-	-	25 119	38 081	-	-	63 200
Electrolysis of Coal Slurries in New Environments	-	-	-	-	-	-	-	-	-	-	-	48 497	11 503	-	60 000
Distributed Chemical and Physical Properties of Coal	-	-	-	-	-	-	-	-	-	-	8 973	30 450	12 538	-	51 961
Magnetic and Electric Properties of Alberta Coals	-	-	-	-	-	-	-	-	-	-	40 397	69 053	-	-	109 450
Distribution of Oxygen Forms in Low-Rank Coals	-	-	-	-	-	-	-	-	-	-	-	21 068	18 932	-	40 000
Subtotal: Other	**0**	**0**	**0**	**0**	**0**	**143 753**	**114 830**	**140 534**	**226 439**	**106 800**	**95 246**	**207 149**	**42 973**	**0**	**1 077 724**

Project Title	1977/78	1978/79	1979/80	1980/81	1981/82	1982/83	1983/84	1984/85	1985/86	1986/87	1987/88	1988/89	1989/90	Projected Future Funding	Total
Department-Funded Projects															
Alberta Coal Geology Project	-	-	-	-	-	-	-	-	-	147 000	553 000	499 761	410 071	49 529	1 659 761
Subtotal: Department-Funded Projects	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**147 000**	**553 000**	**499 761**	**410 071**	**49 529**	**1 659 761**
Total: Alberta Coal Research	**188 746**	**264 972**	**505 521**	**2 119 720**	**4 108 512**	**5 634 927**	**4 797 141**	**4 211 396**	**2 997 736**	**5 488 083**	**4 573 184**	**4 107 903**	**4 387 464**	**1 944 993**	**45 330 298**
Western Canadian Low-Sulphur Coal to Ontario Program															
HYDROSIZER for Fine Coal Recovery from Tailings	-	-	-	-	-	-	-	-	-	-	-	21 000	-	-	21 000
Testing of ARCOFLUX 130	-	-	-	-	-	-	-	-	-	-	-	5 040	-	-	5 040
Thick Seam Extraction and Continuous Haulage Mining Demonstration	-	-	-	-	-	-	-	-	-	-	-	291 773	1 746 540	353 655	2 391 968
Air-Sparged Hydrocyclone	-	-	-	-	-	-	-	-	-	-	-	41 577	86 354	-	127 931
On-Line Coal Analysers	-	-	-	-	-	-	-	-	-	-	-	-	83 733	195 000	278 733
Tailings Reclamation	-	-	-	-	-	-	-	-	-	-	-	3 649	25 182	12 360	41 191
transCOM Co-ordinated Vendor Tests	-	-	-	-	-	-	-	-	-	-	-	-	296 623	500 000	796 623
Total: Western Canadian Low-Sulphur Coal to Ontario Program	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**0**	**363 039**	**2 238 432**	**1 061 015**	**3 662 486**
Total: Coal Research Programs	**188 746**	**264 972**	**505 521**	**2 119 720**	**4 108 512**	**5 634 927**	**4 797 141**	**4 211 396**	**2 997 736**	**5 488 083**	**4 573 184**	**4 470 942**	**6 625 896**	**3 006 008**	**48 992 784**

Figure 1: Research Expenditure on Approved Projects (excluding Coal Research Centre, Devon).

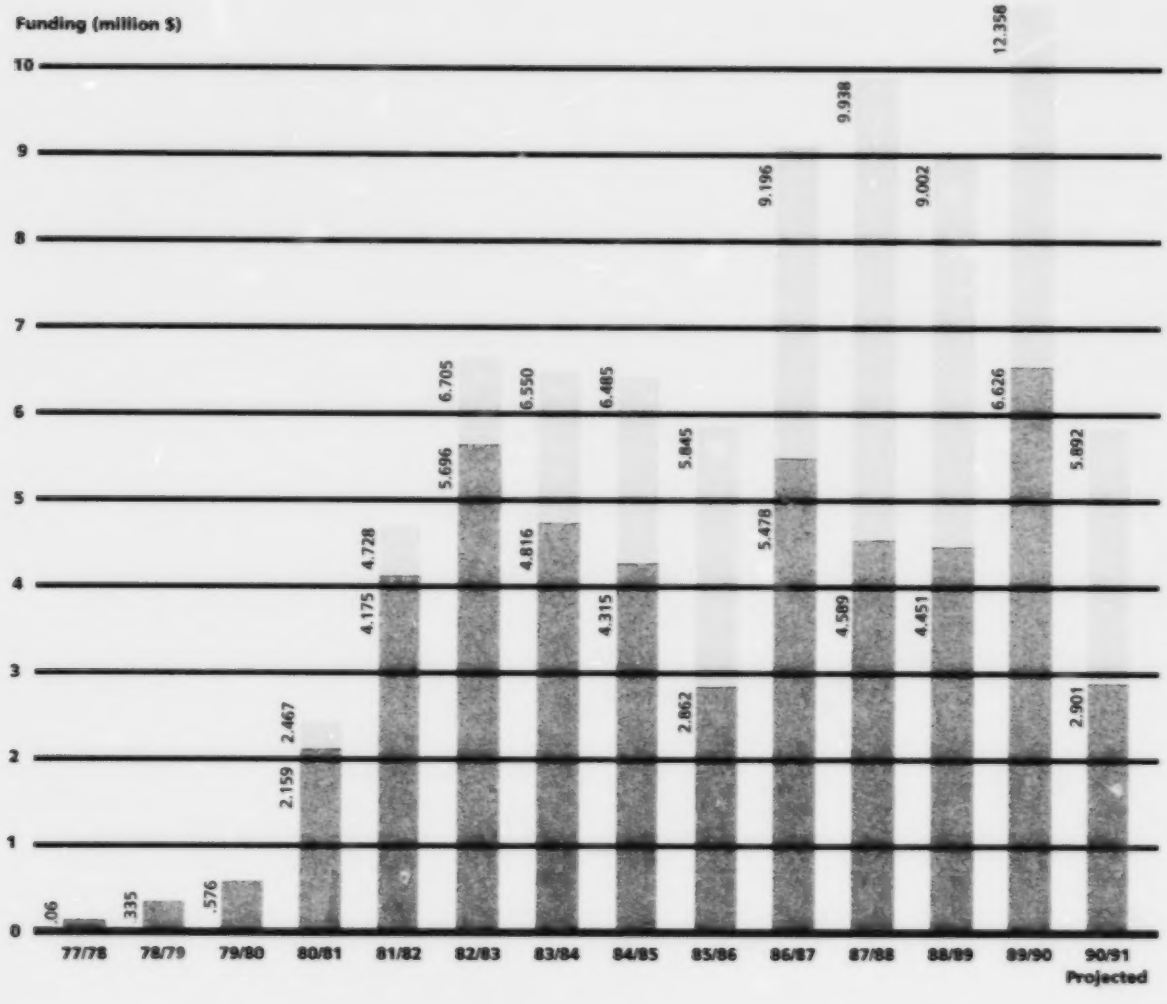
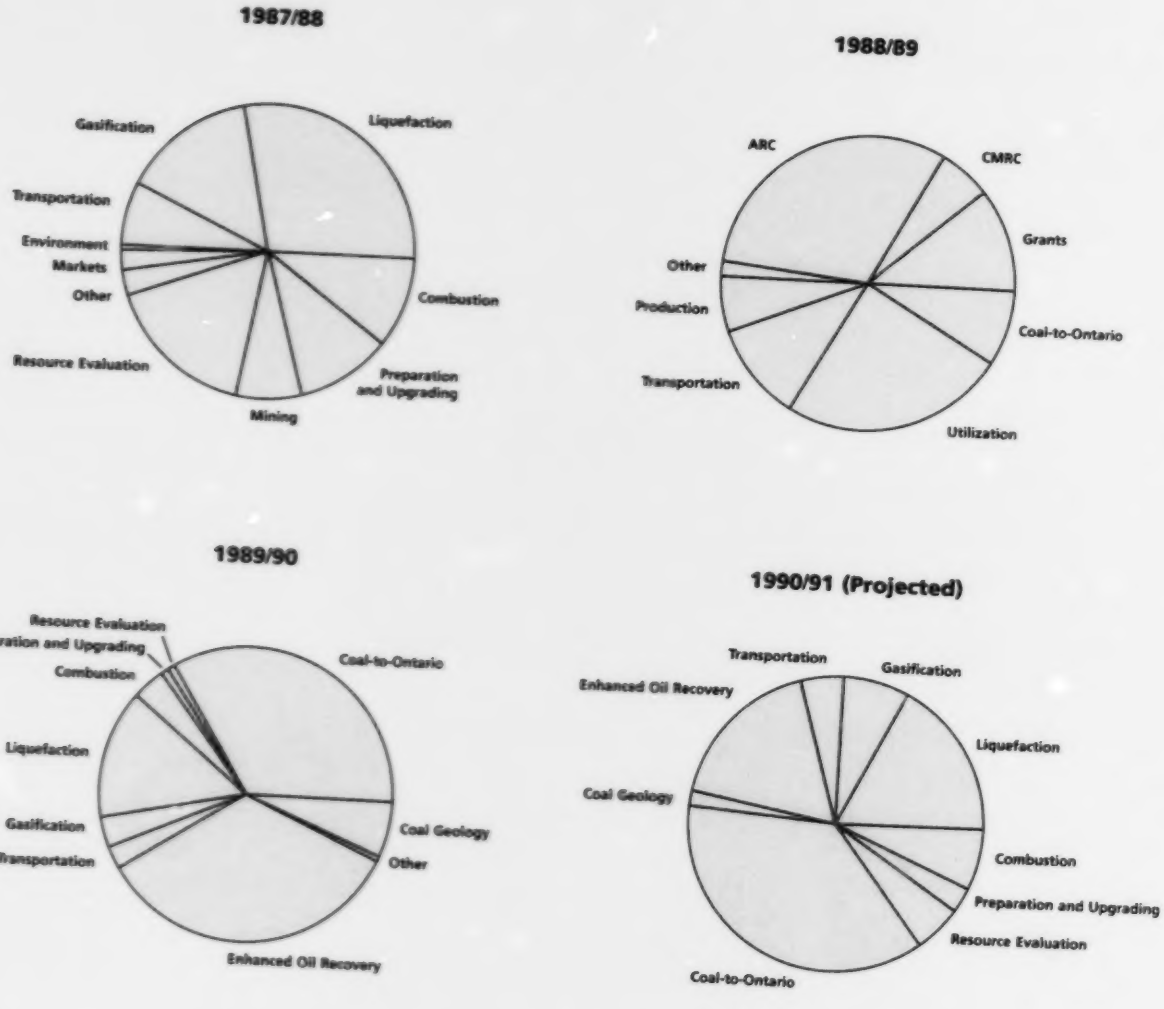


Figure 2: Distribution of Alberta Office of Coal Research and Technology Funding Contributions.



Appendix

Projects Supported by the Alberta Office of Coal Research and Technology and Their Status

A/CERRF-Funded Projects

Project	*Researcher*	*Status*
Resource Evaluation		
Analysis of Coal-Bearing Strata Near Cadomin	H.A.K. Charlesworth, University of Alberta	Completed in 1981/82
Creep Characteristics of Coal	D.M. Cruden, University of Alberta	Completed in 1984/85
Reflective Seismic Investigation of Western Canadian Coalfields	D.C. Lawton, University of Calgary	Completed in 1984/85
Very Low Frequency Geophysical Methods in Coal Exploration	Smoky River Coal Limited	Completed in 1985/86
Potential of Geophysical Techniques for Coal Exploration	Coal Mining Research Company	Completed in 1985/86
Geotechnical Properties of Overburden	Coal Mining Research Company	Completed in 1985/86
Surface Geophysical Coal Exploration	TransAlta Utilities Corporation and Others	Completed in 1986/87
Structural Geometry of Imbricated Thrust Sheets	D.A. Spratt, University of Calgary	Completed in 1986/87
In-Seam Coal Characterization	Coal Mining Research Company	Completed in 1987/88
Seismic Modelling of Shallow Coalfields	D.C. Lawton, University of Calgary	Completed in 1989/90
Downhole Geophysics	TransAlta Utilities Corporation and Others	Continuing
Surface Geophysical Techniques for Foothills and Mountain Coalfield Exploration	Esso Resources Canada Limited and Others	Continuing
Mining		
Support Design for Underground Cavities in Weak Rock	N.R. Morgenstern, University of Alberta	Completed in 1978/79
Coal Mining Research	Coal Mining Research Company	Completed in 1985/86
Coal Mining in 2035	Coal Mining Research Company	Completed in 1985/86

Project	*Researcher*	*Status*
Triaxial Test Development	Coal Mining Research Company	Completed in 1986/87
Ground Movements in Coal Mines	D.M. Cruden, University of Alberta	Completed in 1986/87
Mining 2035 Workshop	Coal Mining Research Company	Completed in 1986/87
Robotics for Mine Control	Coal Mining Research Company	Completed in 1986/87
Non-Cable Vehicle Guidance	Coal Mining Research Company	Completed in 1987/88
Lasers in Coal Mining	Coal Mining Research Company	Completed in 1987/88
Geostatistics	Coal Mining Research Company	Completed in 1987/88
Footwall Anchoring	Smoky River Coal Limited	Completed in 1987/88
Time-Dependent Behaviour of Coal Measure Rocks	R. Day, University of Calgary	Completed in 1988/89
Deformation and Progressive Failure of Open-Pit Highwalls	N.R. Morgenstern, University of Alberta	Completed in 1988/89
Automated Machine Control for Optimized Mining (AMCOM)	Coal Mining Research Company	Completed in 1988/89
Dragline Operations Monitor	Coal Mining Research Company	Completed in 1988/89
Preparation and Upgrading		
Coal Ash Monitoring System	L.R. Plitt, University of Alberta	Completed in 1982/83
Mathematical Modelling of Automedium Cyclones	L.R. Plitt, University of Alberta	Completed in 1984/85
Beneficiation of Coal by Agglomeration in Pipelines	Alberta Research Council/University of Alberta	Completed in 1984/85
Coal Preparation Research	Coal Mining Research Company	Completed in 1985/86
Coal Comminution	Coal Mining Research Company	Completed in 1986/87
Numerical Analysis of Process Yield Losses	Coal Mining Research Company	Completed in 1986/87
Advanced Processes for Low-Rank Coal	Coal Mining Research Company	Completed in 1986/87
Properties of Thermally Dried Coals	Coal Mining Research Company	Completed in 1986/87

Project	*Researcher*	*Status*
Stabilization of Dried Coal	Coal Mining Research Company	Completed in 1986/87
Agglomeration of Low-Rank Alberta Thermal Coals	Alberta Research Council	Completed in 1986/87
Agglomeration for Beneficiation	Manalta Coal Limited	Completed in 1986/87
Preparation and Upgrading Assistance	Coal Mining Research Company	Completed in 1987/88
Moisture and Ash On-Stream Analyser	Coal Mining Research Company	Completed in 1987/88
Recovery of Coal from Tailings	Coal Mining Research Company	Completed in 1987/88
Fine Coal Technical Assistance	Coal Mining Research Company	Completed in 1987/88
Froth Flotation Study at Coal Valley	Luscar Sterco (1977) Ltd.	Completed in 1987/88
Washery Optimization	Coal Mining Research Company	Completed in 1988/89
Coal Beneficiation Process	Gulf Canada Resources Limited and Unocal Canada Limited	Completed in 1988/89
Agglomeration of Coking Coal	Smoky River Coal Limited	Completed in 1988/89
WESTCOAL Separator	Coal Mining Research Company	Completed in 1989/90
Coal Production Program Planning	Coal Mining Research Company	Completed in 1989/90
Electrocoagulation	Luscar Sterco (1977) Ltd. and Others	Continuing
Coal Agglomeration Process Development	Alberta Research Council	Continuing
Particle Distribution in Slurry Flow Through Tees and Manifolds	J.H. Masliyah, University of Alberta	Continuing
Combustion		
Smoky DENSECOAL Combustion Tests	Monenco Consultants Ltd.	Completed in 1985/86
Combustion of Agglomerated Coal	Luscar Ltd.	Completed in 1985/86
Combustion Process Research	Alberta Research Council	Completed in 1986/87
Combustion Characteristics of Alberta Coals	Alberta Research Council	Completed in 1986/87
Combustibility of Agglomerates	Alberta Research Council	Completed in 1986/87
Combustion Program Planning	Alberta Research Council	Completed in 1987/88

Project	*Researcher*	*Status*
Influence of Porosity on Combustion	Alberta Research Council	Completed in 1987/88
Causes of Spontaneous Combustion of Western Canadian Coals	F.W. Bachelor, University of Calgary	Completed in 1987/88
Combustibility of Upgraded Alberta Coals	Alberta Research Council	Completed in 1987/88
Evaluation of Blending on Combustibility	Alberta Research Council	Completed in 1987/88
Prediction of Coal Combustibility	Esso Resources Canada Limited	Completed in 1987/88
Combustion Properties of Alberta Coals and Chars	Alberta Research Council	Completed in 1988/89
Spontaneous Combustion of Thermally Treated Coals	Unocal Canada Limited and Others	Completed in 1988/89
International Energy Agency Basic Coal Combustion Science	Netherlands Energy Research Foundation ECN	Completed in 1988/89
A Thermodynamic Model for the Spontaneous Combustion of Coal	R. Paul, University of Calgary	Completed in 1989/90
Sources of Ash Under Controlled Conditions	R.C. Joshi, University of Calgary	Completed in 1989/90
International Energy Agency Basic Coal Combustion Science - Extension	Netherlands Energy Research Foundation ECN	Continuing
Coal Utilization Program Planning	Alberta Research Council	Continuing
Ash Properties of Alberta Coals	Alberta Research Council	Continuing
Liquefaction		
Coal Liquefaction Study	Kilborn Alberta Limited	Completed in 1981/82
Coal Liquefaction Feasibility Study	Contar Systems Engineering Ltd. and Others	Completed in 1984/85
Synthetic Fuels Program	SRI International	Completed in 1984/85
Economic Evaluation of Coal/Oil Co-processing	HRI Inc.	Completed in 1984/85
PYROSOL Process Review	Canadian Utilities Ltd. and Luscar Ltd.	Completed in 1985/86
Liquefaction Process Improvements	Alberta Research Council	Completed in 1985/86

Project	*Researcher*	*Status*
Hydroprocessing of Coal-Based Liquids	I.G. Dalla Lana, University of Alberta	Completed in 1985/86
Supercritical Gas Extraction of Coal	N. Berkowitz, University of Alberta	Completed in 1985/86
ENR/ARC Coal Conversion Research	Alberta Research Council	Completed in 1986/87
New Liquefaction Processes	Alberta Research Council	Completed in 1986/87
Liquefaction Process Evaluation	Alberta Research Council	Completed in 1986/87
Isotopic Analysis of Co-processing Schemes	K. Muehlenbachs, University of Alberta	Completed in 1986/87
Secondary Upgrading	Alberta Research Council	Completed in 1987/88
Functional Group Analysis of Coal Liquids	M.R. Gray, University of Alberta	Completed in 1987/88
Chemistry of Coal Liquefaction	Alberta Research Council	Completed in 1988/89
Secondary Upgrading of Co-processing Products	Alberta Research Council	Completed in 1988/89
Supercritical Gas Extraction of Coal	N. Berkowitz, University of Alberta	Completed in 1988/89
Liquefaction of Coal with Natural Gas	M.R. Gray, University of Alberta	Completed in 1988/89
Hydroprocessing of Coal-Derived Liquids	I.G. Dalla Lana, University of Alberta	Completed in 1988/89
Isotopic Studies of Coal/Bitumen Co-processing Schemes	K. Muehlenbachs, University of Alberta	Completed in 1989/90
Molecular Interactions Between Heavy Oil and Coal Species During Co-processing	P.D. Clark, University of Calgary	Completed in 1989/90
Product and Process Characterization	Alberta Research Council	Continuing
Co-processing Process Development	Canadian Energy Developments Inc.	Continuing
Combined Processing of Coal, Heavy Oil and Natural Gas	M.R. Gray, University of Alberta	Continuing
Specialty Chemicals from Coal-Derived Liquids	Alberta Research Council	Continuing

Project	*Researcher*	*Status*
Co-processing of Coal with Molten Halide Catalysts	A. Chakma, University of Calgary	Continuing
Gasification		
Gasification of Western Canadian Coals	TransAlta Utilities Corporation and Others	Completed in 1986/87
Fluidized Bed Gasification of Highvale Coal	TransAlta Utilities Corporation and Others	Completed in 1987/88
Economics of Coal Gasification	Alberta Power Limited and Others	Completed in 1987/88
Gasification Process Research	Alberta Research Council	Completed in 1987/88
Gasification Properties of Alberta Coals	Alberta Research Council	Completed in 1987/88
Gasification Laboratory Facilities	Alberta Research Council	Completed in 1987/88
Corrosion in Gasification Systems	W.J.D. Shaw, University of Calgary	Completed in 1987/88
Gasification Characteristics of Alberta Coals	Alberta Research Council	Completed in 1988/89
Devolatilization Properties of Alberta Coals	Alberta Research Council	Completed in 1988/89
IGCC Utility Applications	TransAlta Utilities Corporation and Others	Completed in 1989/90
Gasification Properties of Alberta Coals, II	Alberta Research Council	Continuing
Transportation		
Coal Slurry Pipeline Research	Pembina Resources Ltd.	Completed in 1984/85
Coal/Oil/Natural Gas Transportation System	CERI Energy Research Ltd.	Completed in 1987/88
Coal Market Access Model	Trimac Consulting Services Ltd.	Completed in 1988/89
Coal-Oil Slurry Pipelining	Unocal Canada Limited	Completed in 1988/89
Coal Slurry Technology	Salzgitter Industriebau GmbH and Others	Continuing

Project	*Researcher*	*Status*
Environment		
Coal Conversion Waste-Water Treatment	S.E. Hrudey, University of Alberta	Completed in 1984/85
Low NO_x/SO_x Burner	TransAlta Utilities Corporation	Completed in 1986/87
Coal Conversion Waste-Water Treatment	S.E. Hrudey, University of Alberta	Completed in 1987/88
Coal for Use in Enhanced Oil Recovery: Emission Control Technology	Esso Resources Canada Limited	Completed in 1987/88
Sorbent Injection Study	Alberta Power Limited and Others	Completed in 1988/89
Markets		
Conversion from Oil to Coal-Water Fuels	Smoky River Coal Limited	Completed in 1985/86
Production of Activated Carbon	E.L. Tollefson, University of Calgary	Completed in 1985/86
Activated Carbon From Coal	E.L. Tollefson, University of Calgary	Completed in 1987/88
Enhanced Oil Recovery		
Fuel Options for Enhanced Oil Recovery	L.A. Smith Consulting and Development Ltd.	Completed in 1985/86
Coal Use in Enhanced Oil Recovery	Luscar Ltd. and Others	Completed in 1987/88
Coal-Fired Steam Injection Boiler	Fording Coal Limited and Others	Completed in 1988/89
Application of the LNS Burner to an Oil Field Steam Generator	TransAlta Resources Investment Corporation and Others	Completed in 1988/89
Economics of Coal Use for Heavy Oil Recovery	Shell Canada Limited	Completed in 1989/90
Coal-Condensate Slurry Pipelining	Unocal Canada Limited	Completed in 1989/90
LNS Burner Steam Generator Demonstration	TransAlta Resources Investment Corporation and Esso Resources Canada Limited	Continuing
Other		
Coal Technology Information Centre	Alberta Research Council	Completed in 1985/86

Project	*Researcher*	*Status*
Technical Information Needs	Crozier Information Resources Consulting Ltd.	Completed in 1985/86
Data Gathering for Research Planning	Coal Mining Research Company	Completed in 1986/87
Electrolysis of Coal Slurries	V.I. Birss, University of Calgary	Completed in 1986/87
Sulphur Isotope Studies of Coal	H.R. Krouse, University of Calgary	Completed in 1988/89
Electrolysis of Coal Slurries in New Environments	V.I. Birss, University of Calgary	Completed in 1988/89
Distributed Chemical and Physical Properties of Coal	P.J. Crickmore, University of Alberta	Completed in 1988/89
Magnetic and Electric Properties of Alberta Coals	H.A. Buckmaster, University of Calgary	Completed in 1989/90
Distribution of Oxygen Forms in Western Canadian Low-Rank Coals	N. Berkowitz, University of Alberta	Completed in 1989/90

Department-Funded Project

Alberta Coal Geology Project	Alberta Research Council	Continuing

Western Canadian Low-Sulphur Coal to Ontario Program

HYDROSIZER for Fine Coal Recovery from Tailings	Obed Mountain Coal Company Limited	Completed in 1989/90
Testing of ARCOFLUX 130	Obed Mountain Coal Company Limited	Completed in 1989/90
Thick-Seam Extraction and Continuous Haulage Mining Demonstration	Smoky River Holdings Ltd.	Continuing
Air-Sparged Hydrocyclone	Hydro Processing & Mining Ltd.	Continuing
On-Line Coal Analysers	RadioMetrics Engineering Ltd.	Continuing
Tailings Reclamation	Luscar Sterco (1977) Ltd.	Continuing
transCOM Co-ordinated Vendor Tests	Unocal Canada Limited	Continuing

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